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Application of Thermal Neutron Capture-Gamma Ray Analysis to Oxidized Taconite Beneficiation Process Slurries

By Franklin B. W. Woodbury

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

BUREAU OF MINES
Lindsay D. Norman, Director

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APPLICATION OF THERMAL NEUTRON CAPTURE-GAMMA RAY ANALYSIS TO OXIDIZED TACONITE BENEFICIATION PROCESS SLURRIES

by

Franklin B. W. Woodbury [1]

ABSTRACT

The Bureau of Mines undertook the development and evaluation of a system to provide a simultaneous, on-line determination of both iron and silica in iron ore beneficiation streams as part of a program to improve the efficiency to mineral separation processes. Californium-252 (252-Cf) was the neutron source used in the system for measuring the amounts of silica and iron in bulk slurries by thermal neutron capture-gamma ray spectra analysis.

The theory of thermal neutron capture-gamma ray reactions and their potential application to mineral processing stream analysis is discussed. The prototype system and supporting software developed by the Bureau is described. During the initial phase of the work, both simulated and actual pilot plant slurries were investigated using a 60- to 32-μg 252-Cf neutron source. The percent solids of the slurries was ranged from 2 to 40 percent and the silica and iron content ranged from 1.5 to 83 percent and from 10 to 65 percent, respectively. Accuracy of the determination of the components in the solids was dependent upon the percent solids in the slurry.

INTRODUCTION

Process control in mineral beneficiation is an important factor, because lower grade, variable ore bodies are being treated, and because product quality has to be maintained within prescribed limits. This will be particularly true in the U.S. iron ore industry as oxidized taconites[2] become of increasing importance. Since the oxidized materials do not respond to current methods of low-intensity magnetic separation, alternative methods involving flotation, reduction roasting-magnetic separation, wet high-intensity magnetic separation,

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[1]Metallurgist, Twin Cities Research Center, Bureau of Mines, Twin Cities, Minn. (now Staff Engineer, Mineral Resources Technology, Bureau of Mines, Washington, D.C.).

[2]The term "oxidized taconites" is synonymous with the term "nonmagnetic taconites." Both refer to the iron oxides that are not recovered by a drum-type magnetic separator with a maximum field intensity of 3,000 gauss at the drum surface.

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or combinations of these are being evaluated. Regardless of the method used in the beneficiation of the oxidized materials, some means of process optimization and control will be necessary.

As part of the Bureau of Mines research program on Advancing Minerals Technology, the Twin Cities (Minn.) Research Center undertook the development and evaluation of a system using a 252-Cf neutron source[3] for monitoring taconite process streams. The research represents one phase of a program to augment the U.S. iron resource base through the development of processes to treat oxidized taconites. In this application, the 252-Cf system provides a determination of the iron and silica (elemental silicon) in the process streams.

Chemical composition of the solids in the process streams is of prime concern to mill operators in maintaining grade and recovery, and has been successfully monitored by a variety of techniques. The most notable applications are X-ray fluorescent determination of heavy metal content and nuclear activation methods (12, 16-17, 19).[4] An example of the nuclear activation method is the Neutron On-Line Analyzer (NOLA)[5] being used to monitor the amounts of silica in the dust generated in the crushing of crude feed to a magnetite taconite plant. At the Hoyt Lakes plant of Erie Mining Co. the silica determinations are used to insure a uniform incoming feed by controlling the shovel operation (5, 26). The same type of analyzer is also used for grade control at the Sherman concentrator in Canada (6) and at the Tilden mine in Michigan. Another nuclear activation device that determines silica in small dry samples of taconite concentrates, is the Neutron Activation Laboratory Analyzer (NALA), a modified version of the NOLA system. Since activation analysis methods normally require both an activation interval and a counting interval, they are not suitable for on-line analysis if the radioactive isotope that is formed has a half-life of more than a few minutes. Normally, the combined time interval for both activation and counting is 5 half-lives; however, this time can be decreased if a circulating system is used as in the NOLA device (1, 5). Practical on-line application of activation methods to iron measurements is not feasible since iron forms an activation isotope with a 2.5-hour half-life. In the magnetite taconite industry only the magnetic iron present in the products is measured, no on-line determinations are made of the total iron in the beneficiation process streams. As lower grade iron ores are processed, and both magnetic and oxidized iron minerals are recovered, it will be desirable to determine the iron in the process streams.

The Bureau's research was directed toward the development of a device that would provide the on-line determinations of all elements of interest.

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[3]Californium-252 neutron source was provided under an Interagency Agreement between the U.S. Department of the Interior, Bureau of Mines, and the U.S. Department of Energy.

[4]Underlined numbers in parentheses refer to items in the list of references preceding the appendixes.

[5]Reference to specific brand names is made for identification only and does not imply endorsement by the Bureau of Mines.

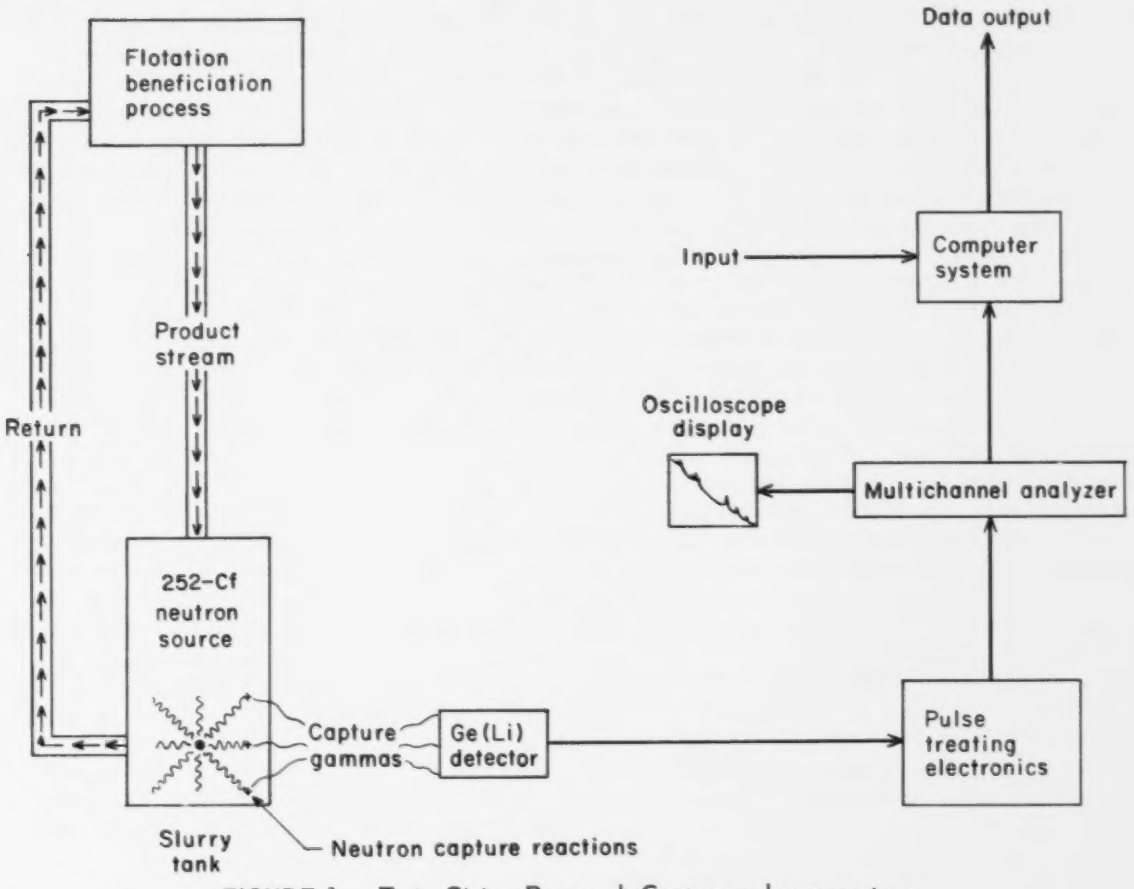

FIGURE 1. - Twin Cities Research Center analyzer system.

The analyzer system shown in figure 1 is based on the Bureau-developed sulfur meter which uses thermal neutron-capture methods to determine the amount of sulfur and iron in coal (25). The capability of determining more than one component at a time makes the method ideal for monitoring both iron and silica in oxidized or magnetite taconite process streams. While small dry samples of taconite have been subjected to thermal neutron capture-gamma ray analysis (10), to date there is no system in industrial use that can provide a rapid measurement of iron and silica in bulk slurries.

THEORY

Thermal neutron capture-gamma ray analysis offers a useful and attractive method by which both qualitative and quantitative determinations can be made on a beneficiation process slurry. The determinations are based on the gamma radiation that is emitted after a nucleus has captured a thermal neutron. A thermal neutron is a free neutron with kinetic energy that has been reduced so that its average energy is equivalent to the kinetic energy of the atoms or molecules in its environment. Since the energy is temperature dependent, neutrons with this kinetic energy are termed thermal neutrons. At room

temperature this energy is 0.025 eV, and the neutron has a velocity of 2,200 m/sec. A neutron loses its energy when it undergoes scattering reactions with nuclei in its environment; for example, in water a 2 MeV neutron would reach thermal energy after less than 27 collisions with hydrogen atoms. Regardless of its energy, a neutron can enter into a number of different types of reactions with nuclei. The probability of any type of neutron interaction occurring is related to the cross section of the target nucleus for that reaction and the energy of the incident neutron. At high energies (> 3 MeV) a neutron loses energy primarily by inelastic scattering; the (n, p) type reactions are also prevalent at these energies. At energies less than the first excited state of the nucleus the neutron loses energy by elastic scattering events until it reaches thermal energy, at which point (n, p) reactions are prevalent. Exceptions to this rule are resonance capture reactions.

At thermal energies a neutron can be captured by a nucleus forming a compound nucleus. The compound nucleus is in a highly excited state and exists only in an intermediate and unstable state that will return to a stable ground state in 10^{-14} to $^{-15}$ sec with the emission of photon energy equivalent to the binding energy of the nucleon. The energy balance for a thermal neutron capture reactions is (20)

$$E_N + M_N + M_A \longrightarrow M_{A+1} + (Q + E_N), \qquad (1)$$

where E_N = initial neutron energy,

M_N = neutron,

M_A = target nuclide,

M_{A+1} = resultant nuclide,

$(Q+E_N)$ = energy of reaction,

and Q = energy that is dissipated in a single or several electromagnetic photons when the resultant nuclide returns to ground state (except for some small nucleus recoil energy).

In terms of the nuclear transmutations, the thermal neutron capture reaction is symbolized by

$$_ZX^A\ (n,\gamma)\ _ZX^{A+1}, \qquad (2)$$

where X = the symbol of the element,

A = mass number (total number of particles in the nucleus),

Z = atomic number (number of protons in the nucleus),

n = the inbound neutron,

and γ = the emitted gamma radiation.

To show the intermediate compound the transmutation is sometimes written as

$$ {}_{Z}X^{A} + n \rightarrow {}_{Z}X^{(A+1)*} \rightarrow {}_{Z}X^{A+1} + \gamma's, \quad (3) $$

where * indicates an intermediate excited state.

The reactions for iron and silicon are

$$ {}_{14}Si^{28} + n \rightarrow {}_{14}Si^{29*} \rightarrow {}_{14}Si^{29} + \gamma's, \quad (4) $$

$$ {}_{26}Fe^{56} + n \rightarrow {}_{26}Fe^{57*} \rightarrow {}_{26}Fe^{57} + \gamma's, \quad (5) $$

where ${}_{14}Si^{29*}$ and ${}_{26}Fe^{57*}$ represent the intermediate excited states that form when a thermal neutron is captured.

The emitted gamma radiation can occur in several intermediate energy steps resulting in a gamma energy distribution characteristic of the original target nucleus. The actual energy distribution will be determined by the energy of the excitation state, the ultimate ground stage, the nuclear structure, and the spin states of the neutrons in the nucleus (3). The emission spectra showing the various possible energy transitions for the intermediate excited state to ground state transitions for Si^{29*} and Fe^{57*} are presented by Bartholomew and Kinsey (4, 15). In addition to the energy emissions from the allowed transition states, other spectrum energies that occur are the result of the manner in which the detector absorbs the initial gamma rays and are termed escape peaks. The energies and relative intensity for the major iron and silicon capture peaks and the associated escape peaks from the gamma ray emission represented by equations 4 and 5 are shown in table 1 (9).

TABLE 1. - Major and associated escape peaks for iron and silicon[1] in neutron capture-gamma ray spectrum for taconite slurries

Element	Primary peak energy, MeV	Intensity, photons per 100 neutrons	First escape peak energy, MeV	Second escape peak energy, MeV
Iron....	7.646	22.14	7.136	6.626
Do....	7.632	27.19	7.122	6.612
Do....	7.279	4.60	6.769	6.259
Do....	6.018	8.08	5.508	4.998
Do....	5.921	8.29	5.410	4.900
Do....	4.810	1.66	4.300	3.790
Do....	4.407	1.31	3.897	3.387
Do....	4.219	4.02	3.709	3.199
Silicon.	7.199	7.16	6.689	6.179
Do....	6.380	12.62	5.870	5.360
Do....	4.934	70.55	4.424	3.914
Do....	3.539	79.58	3.029	[2](2.517)

[1]Major spectrum peaks range between 3 and 8 MeV.

[2]In the initial work the 2.517 MeV Si second escape peak was below the multichannel analyzer discriminator lower energy limits.

Past studies of the neutron capture-gamma rays have contributed to the knowledge of nuclear structure, neutron separation energies, gamma ray transition probabilities, decay schemes, and nuclear energy levels (3). While the information was very important in understanding the structure of matter, little attention was given to the potential industrial application of the neutron capture methods. One reason for the restriction of the research realm was the existing sources for neutrons. Most work was restricted to facilities with nuclear reactors, particle accelerators, or neutron generators. With the development of industrial-type neutron sources, in particular, the high-yield 252-Cf source, industrial application of neutron capture reactions became feasible.

Californium-252 is produced by the irradiation of plutonium, americium and curium in the high flux reactor at Oak Ridge National Laboratory (27). This isotope emits 2.3×10^{12} neutrons per gram per second and provides a neutron flux almost as large as the flux obtainable in most research reactors (21). 252-Cf has been referred to as a "hip pocket" reactor because of its high neutron yield (28). Because of its large neutron yeild per unit mass, 252-Cf is a potential source that could be used in many industrial and medical applications.

In the minerals industry, significant advances in the utilization of 252-Cf were made in mineral exploration methods (11, 22, 24) and in methods of monitoring coal (13, 25). Duffey, Wiggins, and Senftle proposed that 252-Cf should have potential useful application in the taconite industry (11). In these pioneering efforts to find industrial applications for 252-Cf, activation and thermal capture analysis were used.

Activation analysis differs from thermal neutron capture analysis in the mechanism of the reaction and the products formed. While neutron capture analysis measures the gamma emissions of the transition of an intermediate nucleus from its excitation state to ground state, activation analysis measures the radioactive decay emissions from radioactive products. Normally a high energy neutron (above 3 MeV) is required for the formation of activation products. The activation reactions for iron and silicon are

$$ {}_{14}Si^{28}\ (n,p)\ {}_{13}Al^{28} \xrightarrow[t_{1/2} = 2.4 \text{ minutes}]{\gamma,\beta} {}_{14}Si^{28} \qquad (6) $$

$$ {}_{26}Fe^{56}\ (n,p)\ {}_{25}Mn^{56} \xrightarrow[t_{1/2} = 2.58 \text{ hours}]{\gamma,\beta} {}_{26}Fe^{56}. \qquad (7) $$

When the reactions in equations 6 and 7 are compared with the neutron capture reactions for iron and silicon as shown in equations 4 and 5, a number of differences are noted. In equations 6 and 7, after the neutron interacts with the original nucleus, a proton is emitted with a resultant transmutation of the original element into the element with the next smallest atomic number. The new element is unstable and will decay with a characteristic radiation and half-life. If the half-life is relatively short, such as for silicon, activation analysis is a viable method for on-stream measurements; however, if the half-life is long, on-stream measurements are not feasible for the

material (11). Since activated iron has a long half-life relative to the requirement for on-line monitoring, thermal neutron capture-gamma ray analysis was investigated as a potential method for monitoring iron in taconite slurries.

In the neutron capture reactions, the intensity of the gamma rays emitted from the capture reactions is proportional to the amount of the target nuclei present in the sample. The number of interactions (N) that will occur is determined by the number of incident neutrons (I) available for interactions, the number of target element nuclei per cubic centimeter (n), the thickness of the target material in centimeters (X), and the cross section for the capture interaction for the element (σ_c) in square centimeters so that

$$N = In\ \sigma_c X. \tag{8}$$

This simplified formula is true only for a single-component system with a very small thickness and a narrow beam of neutrons. In a slurry, the incident neutrons occur as a diffused neutron flux that is continuously attenuated by multiple nuclear interactions.

The attenuation due to multiple neutron interaction leads to a most important factor in measuring the responses of such reactions. Besides the amount of the element in the target, the thermal neutron capture cross section (σ_c) is a very important variable. A difficulty in determining the composition of taconite process slurries is the very small cross section of silicon (0.16 barn)[6] compared with the larger cross section of iron (2.62 barns). Since for the same neutron flux, iron atoms are at least 16 times more likely to undergo thermal capture reactions than silicon, the resultant number of reactions for iron is much larger than those for silicon. In addition, any neutron captured by iron in a composite slurry is no longer available for a silicon capture. The decrease in the relative neutron flux with respect to silicon results in a further decrease in the intensity of the silicon spectrum. Since the actual number of reactions that can occur with any one component in a complex target will be modified by the reactions with other components, the resultant gamma spectrum reflects the composition of the total target. Therefore, equation 8 should be modified to reflect the total interactions.

$$N_T = N_1 + N_2 + \ldots + N_i, \tag{9}$$

$$N_1 = (In_1\sigma_1/\Sigma_T)\quad 1\text{-}\exp(-X\Sigma_T), \tag{10}$$

$$N_1 = (In_2\sigma_2/\Sigma_T)\quad 1\text{-}\exp(-X\Sigma_T), \tag{11}$$

$$N_i = (In_i\sigma_i/\Sigma_T)\quad 1\text{-}\exp(-X\Sigma_T), \tag{12}$$

where Σ_T = total macroscopic cross section for all reactions for all components in the slurry,

---

[6] One barn = 10^{-24} cm^2.

$\sigma_1, \sigma_2, \ldots \sigma_i$ = microscopic capture cross section of the 1st, 2d, and ith elements, respectively,

X = sample thickness,

and $n_1, n_2, \ldots n_i$ = number of target nuclei of the 1st, 2d, and ith elements, respectively.

A further complication could result from self-attentuation of the gamma rays by the target material itself. Since the major capture gamma rays in the iron-silicon system are fairly energetic (3 to 8 MeV), self-attenuation within a taconite slurry would be minor.

The thermal capture method also overcomes the problems related to representative sampling and sample presentation that are common in X-ray fluorescence and other methods (7). These problems associated with X-ray measure occur because of the low energy of X-ray beams and their poor penetrating power. A major problem in measuring beneficiation process streams with X-rays is the need for a very thin window between the X-ray device and the target slurry. The thin window undergoes severe wear due to the abrasiveness of the process slurries. In addition, the X-rays that pass through the window have only a limited penetration into the slurry stream, thus only the composition of the first few monolayers in the slurry is measured by X-ray radiation. Because of the inhomogeneity in the cross-sectional distribution of the slurry components, especially near the container walls, the X-ray response may not be representative of the composition of the bulk slurry. Neutrons, with their deep penetration into the process stream and resultant emissions of high-energy gamma rays, provide a response directly related to the amount of each element in the bulk stream and minimize the effect of the inhomogeneities in the stream cross section.

APPARATUS

The 252-Cf laboratory was set up adjacent to a 410-kg/hr (900 lb/hr) beneficiation pilot plant that is capable of processing ores by magnetic separation and/or flotation. The laboratory contains an irradiation room on the ground level and an instrumentation room on the upper level (fig. 2). Equipment located in the irradiation room includes a slurry irradiation tank with attached mixer, a Ge(Li) detector, the circulating pump, and an isotope storage well. The cylindrical stainless steel irradiation tank is 61 cm (2 feet) in diameter by 91 cm (3 feet) deep (fig. 3). A 2.54-cm-diam (1-inch) zirconium oxide combustion tube is used as a source holder to prevent unnecessary abrasion wear of the 252-Cf source encapsulation. Zirconium oxide was used because it creates a very small background contribution to the spectrum signal (23). The tube is mounted on a fixed track so that the distance between the neutron source and tank wall can be varied. The solids in the slurries are maintained in suspension by a 248-w (1/3 hp) mixer.

The 252-Cf source was provided to the Bureau of Mines by the U.S. Department of Energy on an interagency loan, as part of the 252-Cf Market Evaluation Program. Initial work on the single-component slurries was performed when the

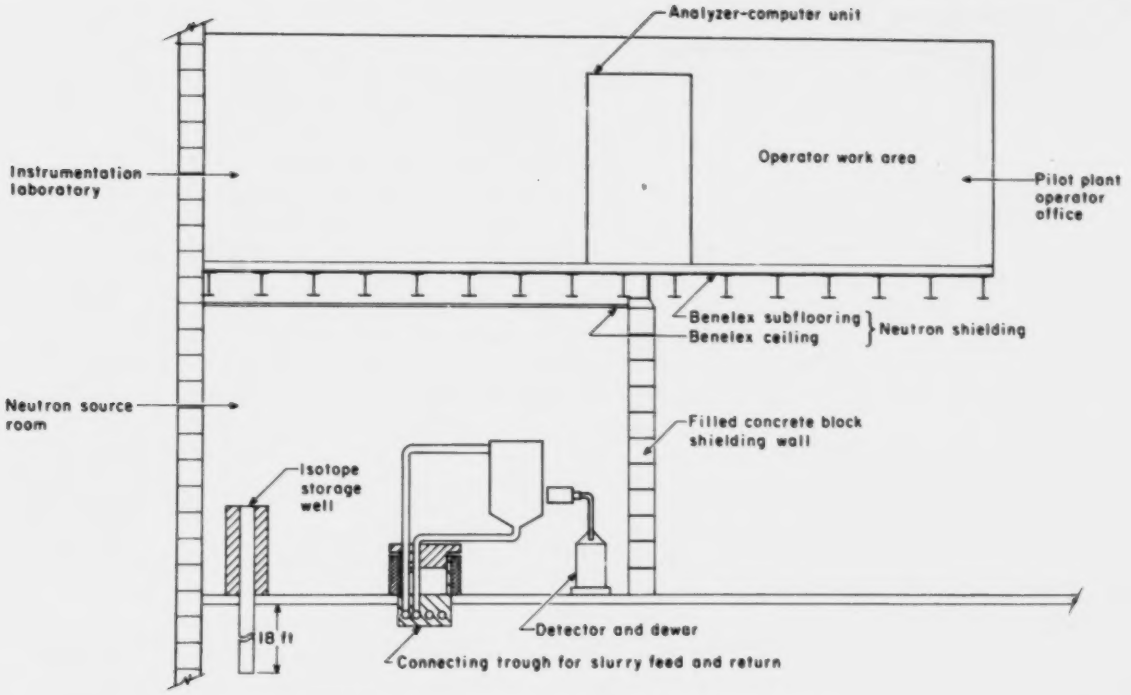

FIGURE 2. - Cross section of analyzer facility.

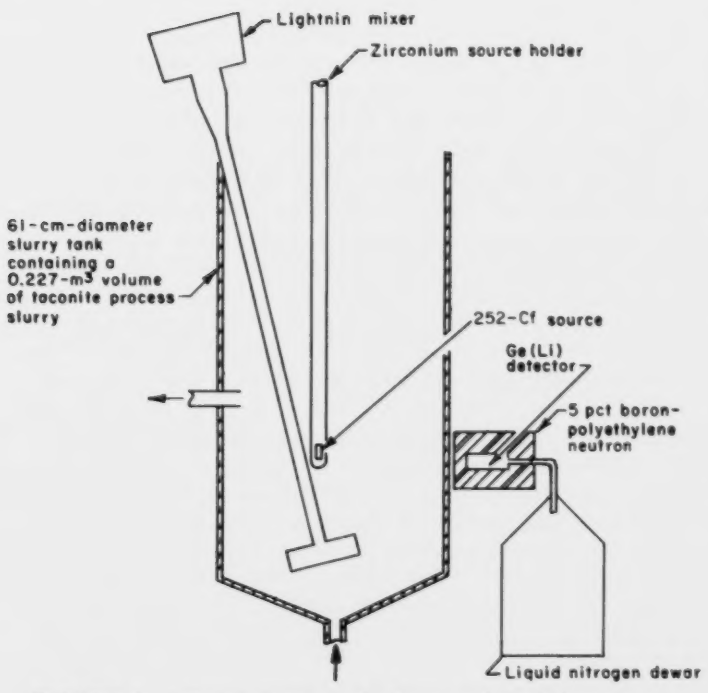

FIGURE 3. - Cross section of slurry tank and detector.

source contained 53 μg of 252-Cf. The research on pilot plant slurries was performed when the source had decayed to 32 μg.

A coaxial Ge(Li) detector with a total active volume of 53 cm^3 is used to detect the gamma rays. A germanium semiconductor detector was selected over a NaI(Tl) scintillation detector because of its superior peak resolution (18). To limit the neutron damage to the Ge(Li) device, the detector and preamplifier are shielded by a 5.1-cm (2-inch) thickness of 5 percent boron-polyethylene shield as indicated in figure 3. All of these items, as well as

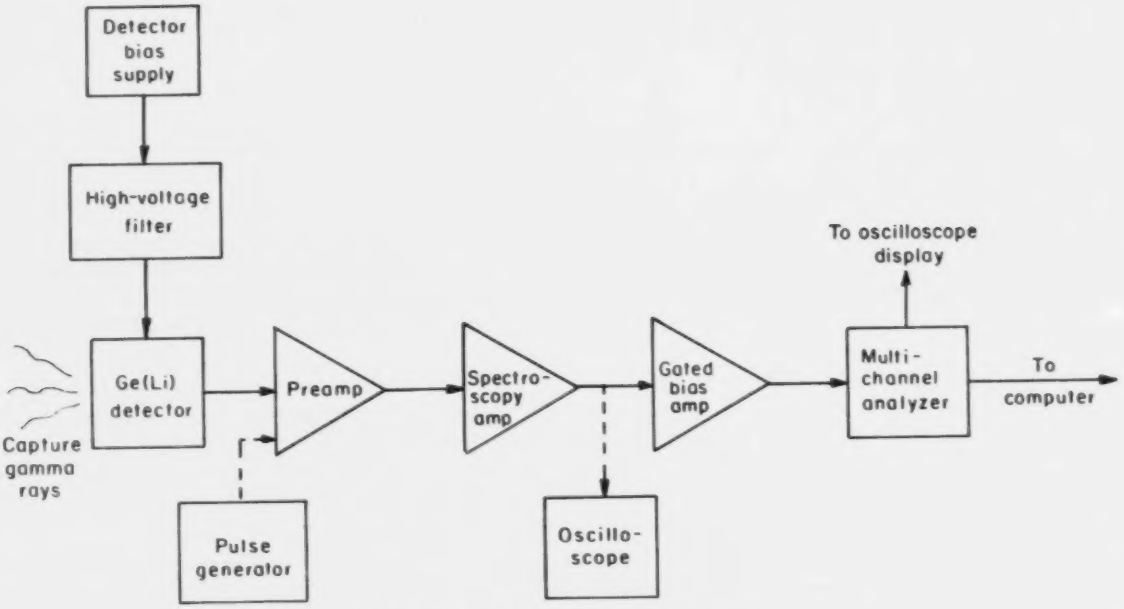

FIGURE 4. - Electronic components.

the entire electronics package and computer shown in figure 4, are commercially available. Signals from the detector preamplifier are carried by cable to the instrumentation room and treated by a spectroscopy amplifier and a gated biased amplifier before being input into a 1,024-channel multichannel analyzer (MCA) for pulse height analysis. The MCA was interfaced into a Hewlett-Packard minicomputer system. The minicomputer has a 32K word memory and a mass data storage device. Since the computer operates within a disc operating system (DOS), special support software was written to link the MCA to the computer. The support software consists of a MCA system library, the MCA data transfer driver, and the MCA function control driver. Together with miscellaneous software routines, the support package allows for complete program control of the MCA operation and data transfer between the MCA, computer, and/or disc storage. A complete description of the Bureau's software package is given in appendix A.

PROCEDURE

In the flotation pilot plant the typical process stream flowrate is 18.9 l/min (5 gal/min). Within the process, a change in the operating parameters results in about a 30-min lag before product composition is reestablished. A test volume of 227 liters (60 gal) was selected to provide adequate materials

for nuclear interactions. A sample counting time of 20 min was selected as a compromise between good nuclear counting statistics and the need to provide rapid determination of slurry components, and to compensate for the pilot plant's low flowrates.

An initial spectrum analysis range of 3 to 8 MeV was selected and covered the expected major iron and silicon peaks while eliminating the hydrogen peak and Compton background below 3 MeV. With the 1,024-channel MCA, the resultant system resolution was 4.9 keV per channel and was adequate for partial resolution of the major iron doublet peaks. Using a blank sample (irradiation tank filled with water only), initial system calibration was performed by the identification of the iron capture gamma doublet at 7.632 and 7.646 MeV and its associated escape peaks. The peaks in the blank sample resulted from neutron captures in the stainless steel tank wall.

Quartz slurries, slurries consisting of mixtures of quartz with magnetite and/or hematite, and actual process slurries from the pilot plant were used to evaluate the analyzer system. All of the tests were made on batch slurry samples. Except for actual pilot plant products, the test slurries were made by mixing the desired amount of solid materials and water so that the total volume was 227 liters (60 gal). In tests where solids were added to vary the chemical composition of the slurry, adjustments were made to maintain the slurry volume at the desired level.

With the neutron source in the irradiation tank, a 20-min spectrum was accumulated for each test slurry; for certain slurries, up to five or more spectra were accumulated and stored for use in precision calculations. After all accumulations were completed on a test slurry, and before any solid or liquid adjustment was made, three to six "dip" samples were taken. Wet- and dry-weight measurements were made on the samples to determine the percent solids. The dry residue was analyzed for iron and silica and the chemical analyses and percent solids determination were then used to calculate the iron and silica compositions of the original slurries. The results were compared with the thermal neutron determined compositions of the slurries.

NEUTRON FLUX DISTRIBUTION AND SYSTEM GEOMETRY

Tests to determine neutron flux distribution in the slurry irradiation tank were made with the tank filled only with water. The flux tests could not be performed with slurries in the tank because the foil locations could not be held fixed in an agitated slurry. The flux was calculated from the activity induced in indium foils placed at selected distances from the neutron source. The results of the tests and measurements are shown in figure 5. Using the flux information, a number of tests were made to determine the best relationship between the source, slurry irradiation tank wall, and the Ge(Li) detector. An optimum system geometry was determined that would provide a maximum number of target nuclei for thermal neutron capture reactions without interposing an inordinate amount of self-shielding. Self-shielding by the target slurry results in distortion in the spectrum peaks. Some of the distortion results due to increased Compton scattering when the gamma ray must exit through more slurry before reaching the detector. Some statistical

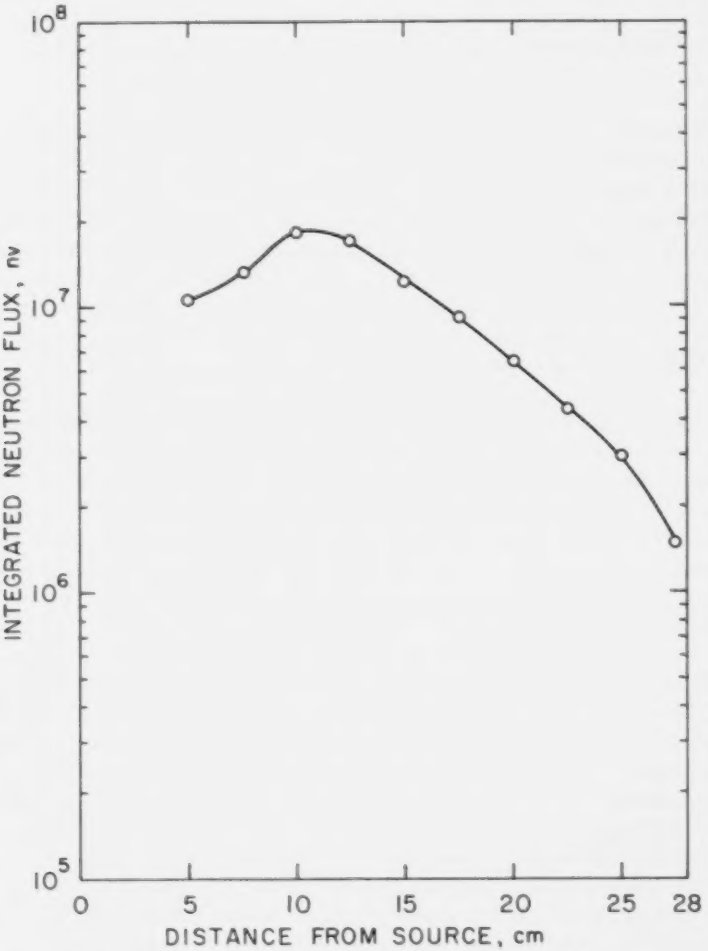

FIGURE 5. - Integrated flux distribution in slurry irradiation tank.

broadening of the peaks occur due to the additional scattering effects caused by the additional distance the primary and secondary gamma rays must travel through the target slurry. The relationship of source location with respect to the tank wall toward the detector is shown in figure 6. If the source was moved closer than 19.05 cm (7.5 inches) to the tank forward wall (toward the detector), the gamma count rate from tank wall neutron capture saturated the detector preamplifier causing complete loss of signal. Between 19.05 cm (7.5 inches) and 30.48 cm (12 inches) from the tank forward wall, the neutron flux at the detector was still of sufficient intensity to give a germanium capture peak in the spectrum, suggesting a high probability of eventual neutron damage to the detector. The optimum distance was between 30.48 cm (12 inches) and 35.56 cm (14 inches) from the tank forward wall. At a greater distance, peak heights were decreased, while the Compton continuum was increased.

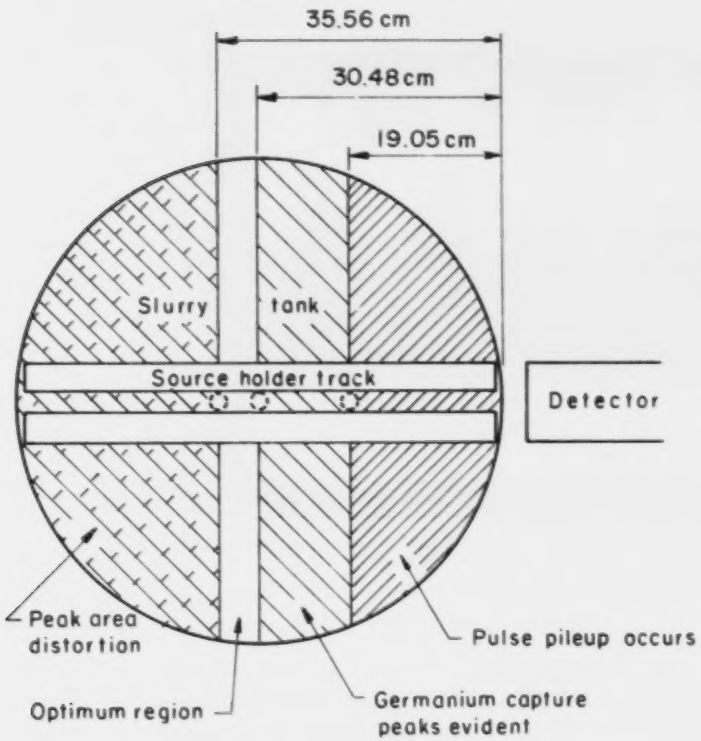

FIGURE 6. - System geometry and detector response (top view).

SPECTRUM DATA EVALUATION

Since the thermal neutron capture-gamma ray spectra are very complex, the evaluation of the capture spectra require computer data processing. Data accumulation, acquisition, and storage were handled by special MCA-computer software. With the software any spectrum can be stored on the disc-storage device and then quickly recalled for data processing allowing considerable flexibility in reevaluating the spectrum data without destroying the original.

To obtain peak area measurements, the following items must be considered in evaluating spectrum data (31):

1. Spectrum smoothing.
2. Shape and intensity of Compton continuum.
3. Resolution of peaks, that are not singlets.
4. Calculation of peak areas.
5. Minimization of errors in the calculated intensities of relatively small peaks.
6. Energy calibration.
7. Peak identification.

The first items in the list caused some early problems because of both the high background and the noise levels relative to the spectrum signal. Acoustical and vibrational effects caused by pilot plant equipment, such as the ball mill, rodmill, and vibrating screen, were picked up by the Ge(Li) detector, which can act as an acoustical amplifier. The oscilloscope photographs in figure 7 show the effects of noise on the preamplifier signal. The amplitude of the sonic noise in the spectrum signal increased when the plant was in operation. Tests showed that the frequency of the major harmonic in the noise was 2.5×10^3 Hz, which is in the sonic range. Random

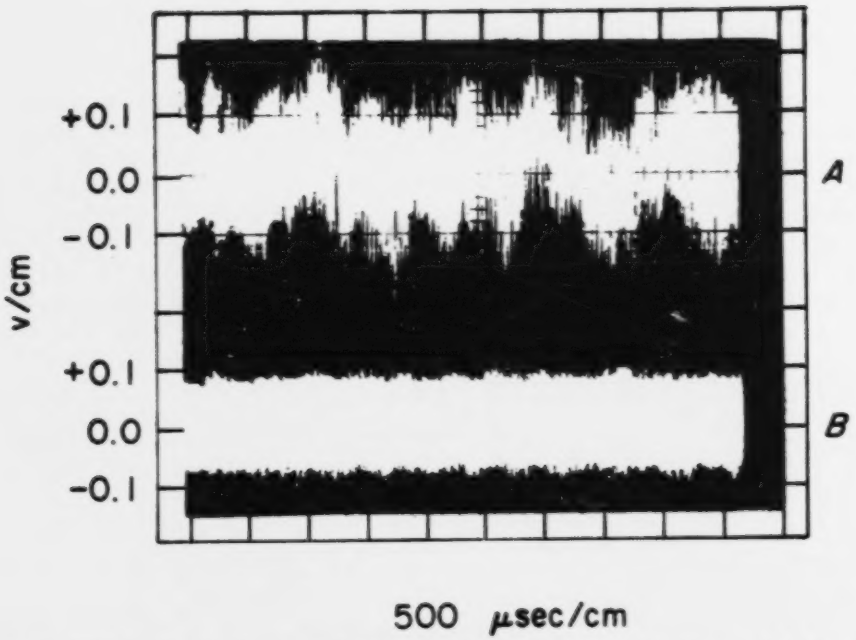

FIGURE 7. - Effects of pilot plant equipment noise on spectrum signal. *A*, Upper spectrum was taken during pilot plant operations and shows the effect on spectrum signal due to sonic noise; *B*, lower spectrum taken when pilot plant was not running and shows the signal without sonic noise.

amplitude spikes were associated with the intermittent action of the vibrating screen. Since the periodicity of the effects of the noise in the spectrum is considerably different from that of the spectrum signal, Fourier transformation can be used to filter out most of these effects. GAMANL, a computer program that uses Fourier transforms to accomplish noise filtering and spectrum smoothing, was obtained from MIT (Massachusetts Institute of Technology) (14). A representation of a spectrum before and after GAMANL processing is shown in figure 8.

While peak energy identification, Compton background subtraction, and peak response calculations were accomplished by GAMANL, the resolution of multiple peaks and small-peak responses were not obtained. Difficulties with peak resolution were due to the MCA system sensitivity of only 2.3 channels full-width half-maximum (FWHM). To properly accomplish the calculations would require a FWHM of greater than five channels; however, this was not possible if the entire energy range of interest was to be covered with the available equipment. Because of the narrow FWHM, a modified Wasson method of peak analysis was used (2). While the Wasson method was effective for evaluating most peak area in the spectrum, it required prior knowledge of the location of the starting and ending channels of the peak and assumed a linear background under the peak. Minor shifts in peak location due to the nonlinearity of the spectrum energy distribution resulted in errors in the peak area calculations.

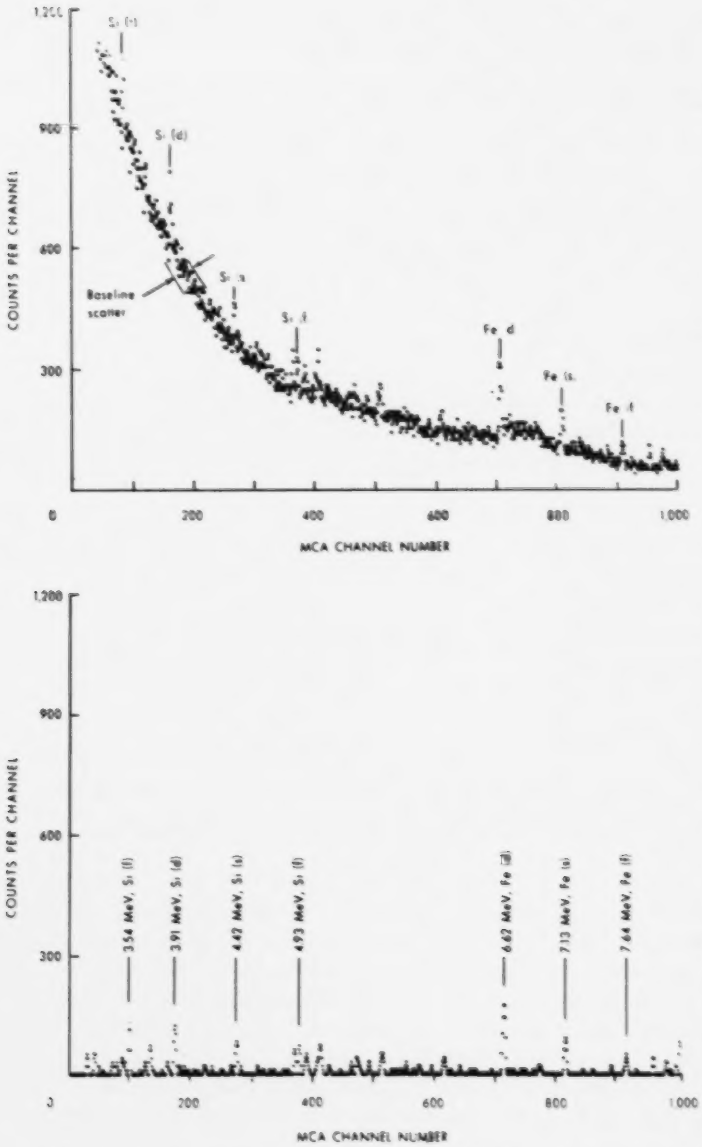

FIGURE 8. - Spectrum before and after GAMANL processing.

RESULTS AND DISCUSSION

Slurries consisting of minus 150-mesh quartz and water were used in the silica calibration tests. The initial slurry contained 2.27 kg (5 lb) of quartz. The amount of quartz in the slurry was increased in incremental steps of 2.27 kg. This test series measured the combined effects of increasing amounts of silica and increasing percent solids in the slurry. Silicon capture peaks at 3.539, 3.914, 4.424, and 4.934 MeV increased in magnitude with each quartz addition. A comparison between the resultant spectra for a slurry containing 4.3 percent (13.62 kg) and 1.3 percent (2.27 kg) silica is shown in figure 9.

The silica test series for the 4.934-MeV silicon peak is summarized in table 2. Using a magnetite concentrate containing less than 2 percent silica, a test series similar to the quartz series was run to determine the iron response. The iron capture peaks increased in magnitude with increasing amounts of material in the slurry; the results are shown in table 3. Curves for both the silicon and iron peak responses are shown in figure 10. These tests demonstrated the ability of the thermal neutron capture method to detect changes in amounts of iron and silicon in a slurry.

TABLE 2. - Variation of counts under the 4.934-MeV silicon peaks as a function of silica content[1]

Silica in slurry, mean percent	Counts in the 4.934-MeV silicon peak	Calculated percent	
		Silica	Deviation
1.28	210	1.32	-0.04
2.53	405	2.48	-.05
3.06	537	3.27	-.21
3.67	566	3.45	-.22
4.00	642	3.92	-.10
4.32	732	4.44	-.12

[1]A source size of 53 μg was used.

TABLE 3. - Variation of counts under the 7.632-7.646-MeV iron doublet peak as a function of iron content[1]

Iron in slurry, mean percent	Counts in the 7.632-7.646-MeV iron doublet peak	Calculated percent	
		Iron	Deviation
Water[2]	508	0.08	-0.08
0.58	871	.73	-.15
1.17	962	.89	.28
1.74	1,418	1.71	.03
2.31	1,785	2.37	-.06
2.87	2,078	2.89	-.02
3.42	2,374	3.42	.01
3.97	2,683	3.97	.00

[1]A source size of 53 μg was used.
[2]The 508 counts occurring in the blank sample (water only) resulted from neutron capture reactions with iron atoms in the walls of the slurry irradiation tank.

The iron results shown in figure 10 are similar to those obtained by Dibbs, Dalton, and Nargolwalla (8), but they differ since Dibbs measured changes over an integrated range of 3 MeV rather than changes in individual peaks. In the silica tests of Dibbs, when he used a similar volume of material and an integrated range technique, only a small change was noted between the blank tests and tests containing up to 90.7 kg (200 lb) of silica in the slurry. The present work detected a change in the peak response of silicon when as little as 2.27 kg (5 lb) of quartz were added to the slurry.

Subsequent tests were made on prepared multicomponent slurries and actual process slurries. The prepared taconite slurries were made by adding quartz and/or hematite to a high-grade magnetite concentrate. While definite changes were noticed in the iron and silicon peaks in the neutron capture spectra of the prepared slurries, the correlation of peak area measurements to the wet-chemical analysis was not always satisfactory. Perturbations in the expected nuclear response obtained with some of the prepared slurries may have been related to slurry stratification due to differences in particles size, varying density of the mixed materials, and in the minerals distribution in the particles. Examination of the photomicrographs in figures 11-12 may help in understanding the abnormal responses that occurred with the prepared slurries

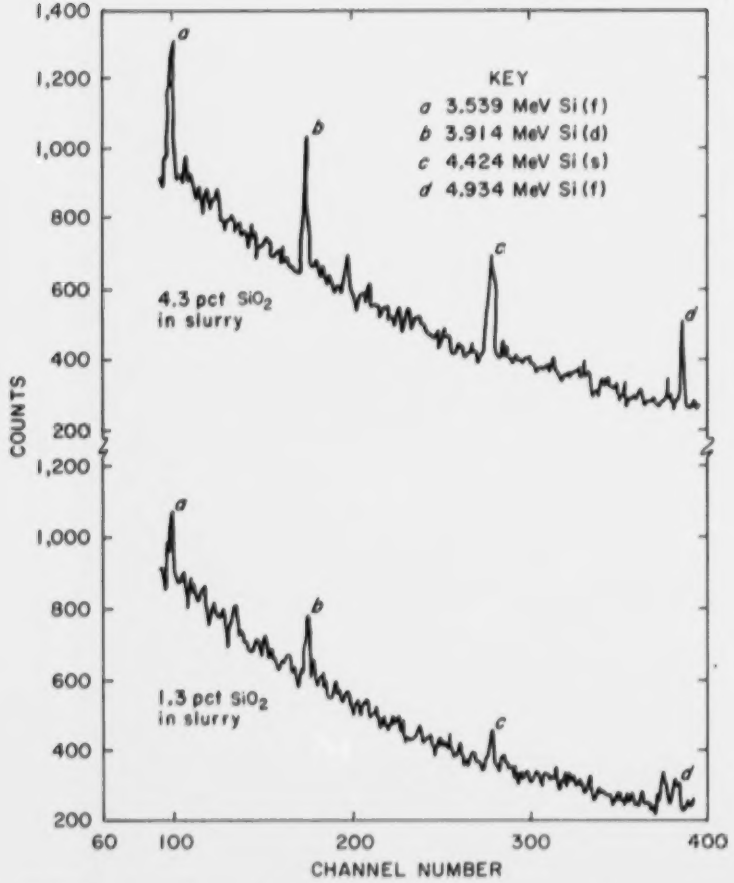

FIGURE 9. - Comparison of thermal neutron capture spectra for 4.3 and 1.3 percent quartz slurries.

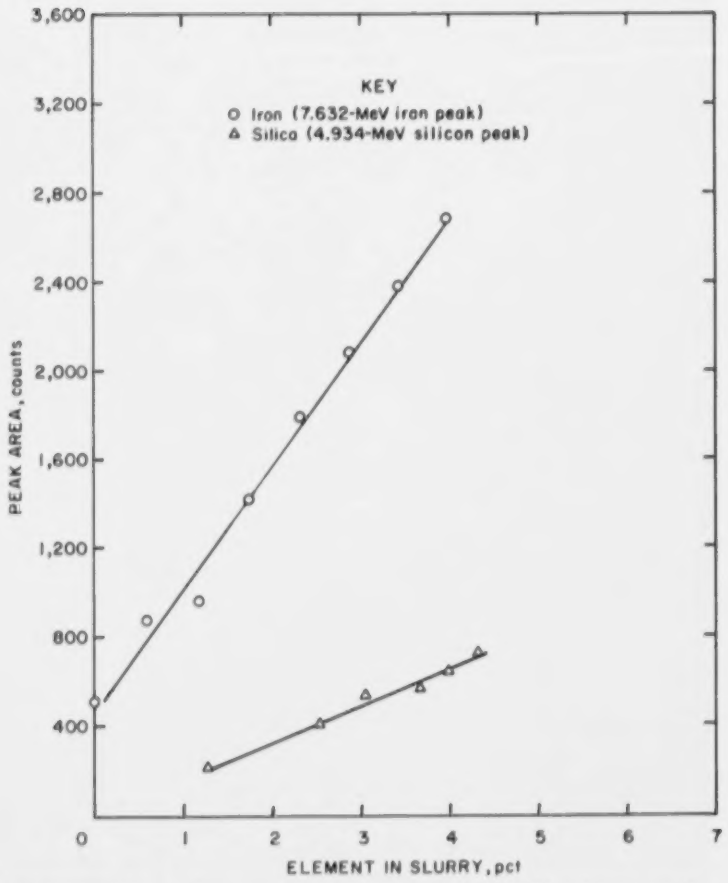

FIGURE 10. - Response curves for 4.934 MeV silicon peak and 7.632-7.646 MeV iron doublet peak.

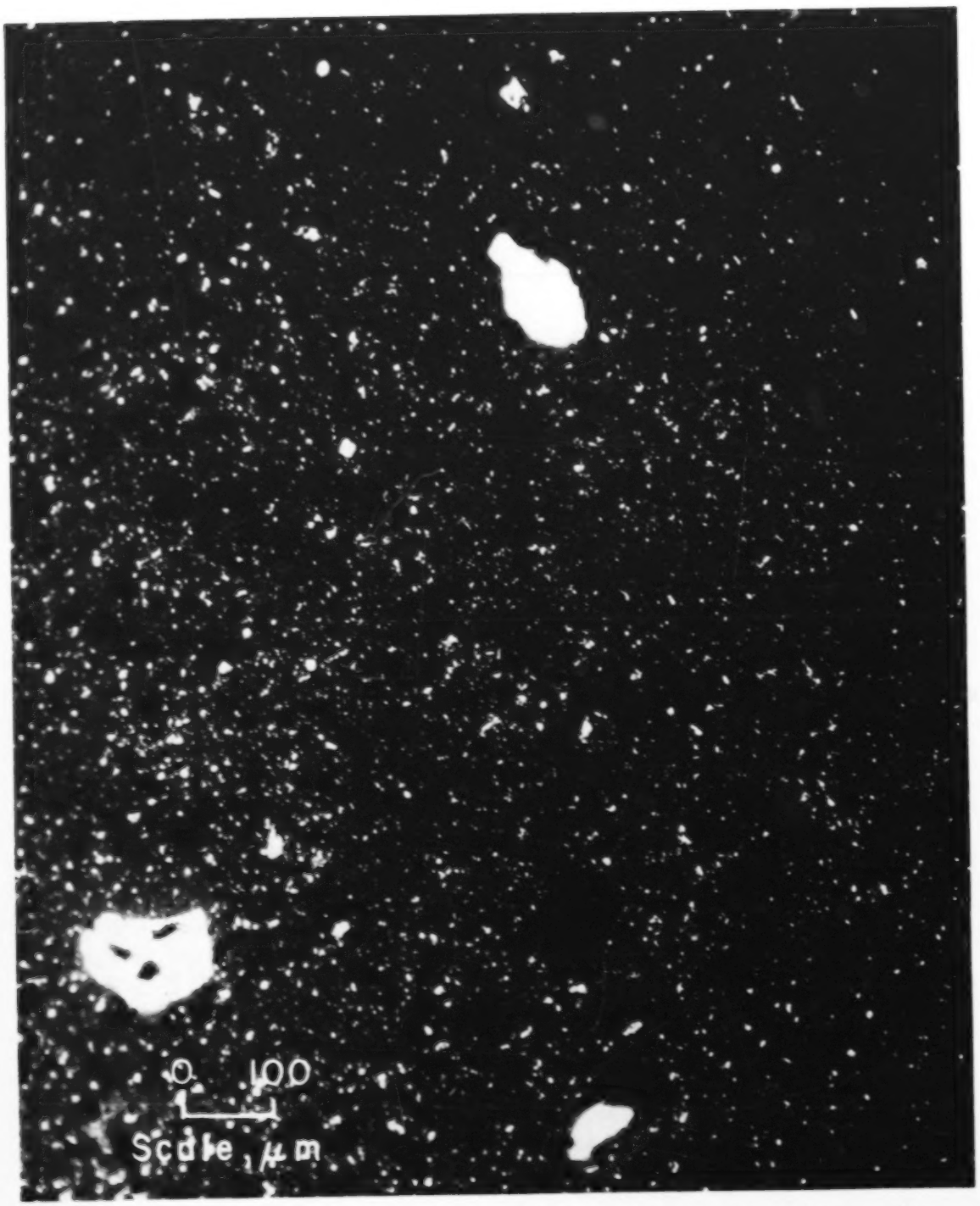

FIGURE 11. - Hematite concentrate. Light and dark particles are quartz and iron oxides, respectively.

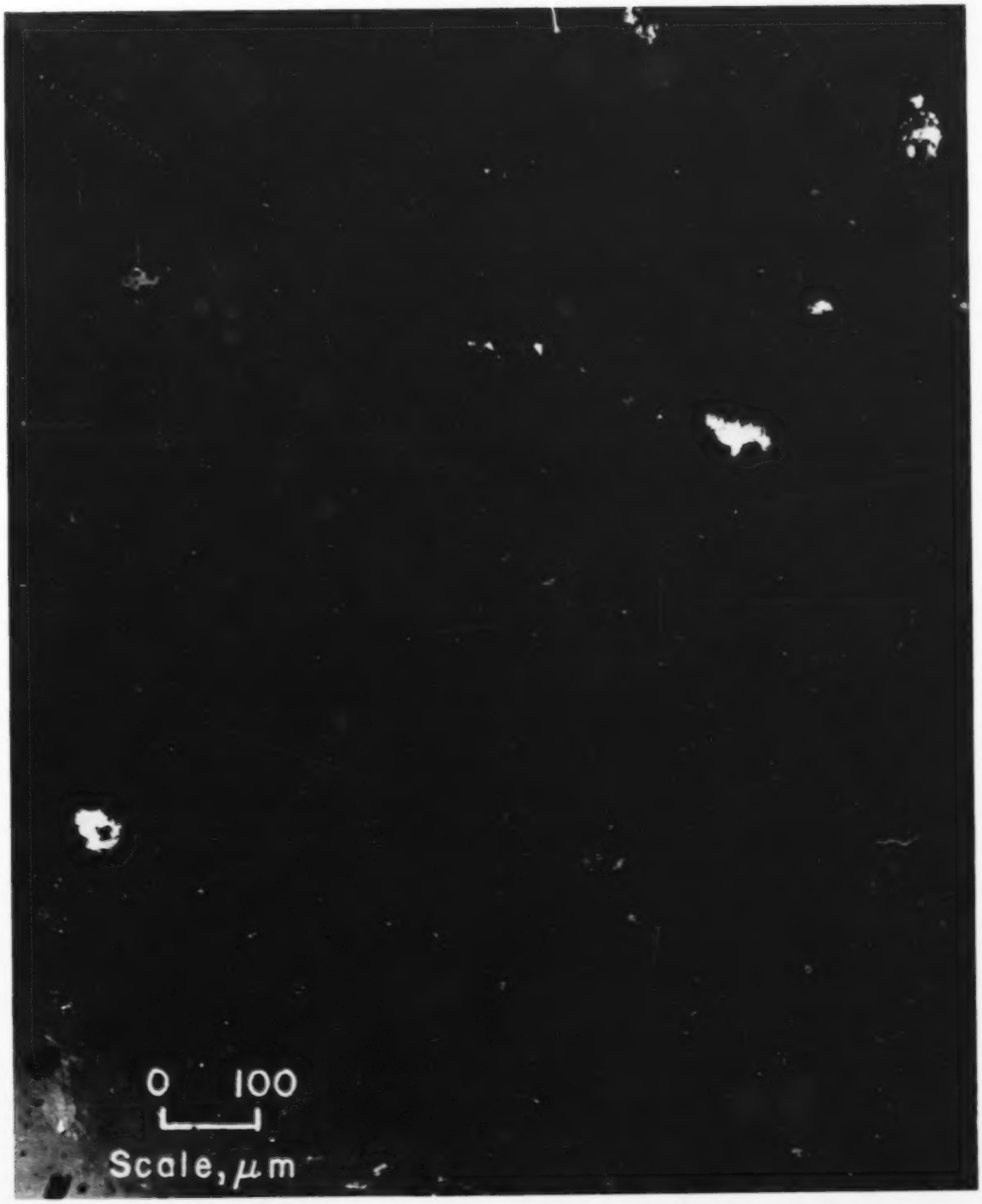

FIGURE 12. - Hematite-magnetite-quartz mixture. Light and dark particles are quartz and iron oxides, respectively.

containing a mixture of magnetite and hematite materials. In the hematite concentrate slurry shown in figure 11, the quartz (silica) particles are fairly uniformly distributed. In the prepared slurry shown in figure 12 the quartz is not as uniformly distributed, and some of the fine iron oxide particles are magnetically flocculated in clusters and chains. The non-uniformity in the size and shape of iron oxide and quartz particles in the prepared slurries resulted in a more heterogeneous target for the neutron interactions and caused variations in the nuclear responses.

Another deviation from the expected behavior occurred during subsequent tests to determine the precision of the peak area measurements. Five repeat spectra were accumulated for a slurry, and the peak area measurements were compared for precision. These tests showed that the counts in the major iron and silicon peaks had relative deviations[7] of less than 0.02 and 0.05, respectively; however at least one spectrum in each series gave a peak measurement with a larger deviation than the other spectra. The continuous exposure of the same slurry to neutron bombardment increases the probability of isotopic or nuclear transmutations which would then cause minor changes in slurry composition during the replication tests series. This problem would not occur in a plant application because plant slurries would not be subjected to long-term irradiation.

After demonstrating that the 252-Cf analyzer could measure iron and silica in the prepared slurries, research was undertaken on pilot plant slurries obtained during the beneficiation of Western Mesabi Range oxidized taconites. Batch samples were taken at the points indicated on the selective flocculation-flotation flowsheet shown in figure 13. Monitoring slurries at S-1, S-5, and S-6 would provide data for determining iron recovery. Monitoring at S-2, S-3, and S-4 would provide data that could be used to control the selective flocculation and flotation process. The solids content and chemical analyses of the batch samples taken are given in table 4.

TABLE 4. - Solids content and wet-chemical analyses of slurries

Sample	Process stream	Solids, wt-pct	Iron in solids, percent	Silica in solids, percent
S-2...	Cyclone overflow.....	15.6	36.6	43.5
S-3...	Flotation tailing 1...	14.7	10.4	82.9
S-4...	Flotation tailing 2...	9.4	17.2	72.8
S-6...	Combined slime tailing	40.3	14.9	75.3

Analysis for samples taken from the rodmill discharge (S-1) and the concentrate stream (S-5) are not reported in table 4 because of errors in the sampling procedure for the samples taken for wet chemical analyses at these points. The thermal neutron capture responses for iron and silicon are shown in figure 14.

[7] Relative standard deviation (RSD) is defined by Analytical Chemistry in the "Guide For Use of Terms in Reporting Data" as a measure of precision within a set of 5 or more determinations. The RSD is "the Standard Deviation expressed as a fraction of the mean, s/x."

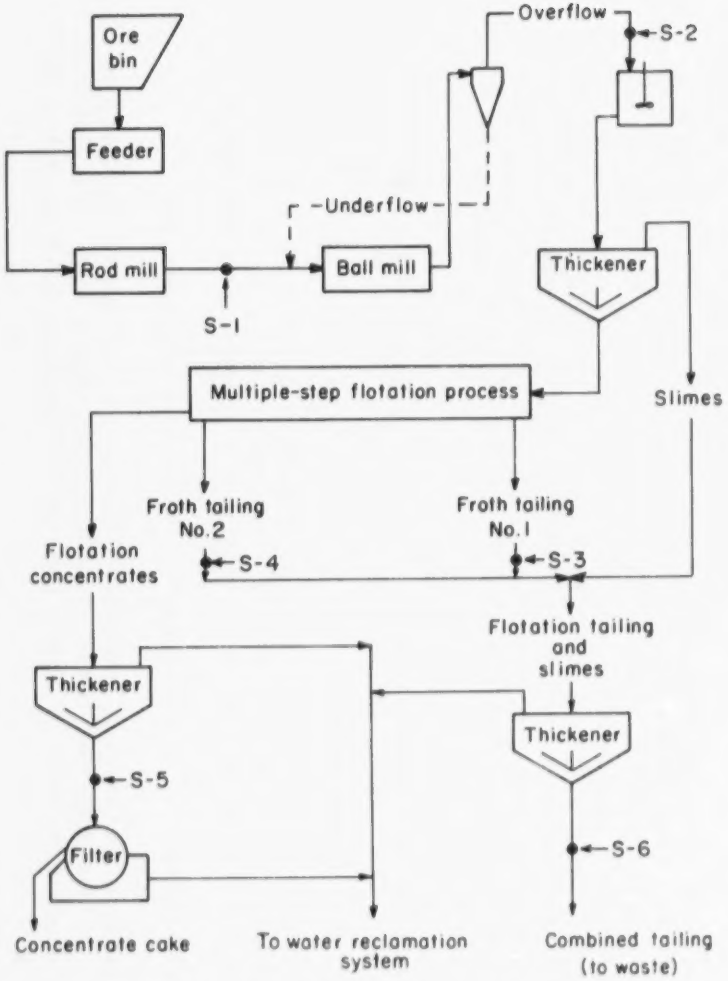

FIGURE 13. - Pilot plant flowsheet and sample points.

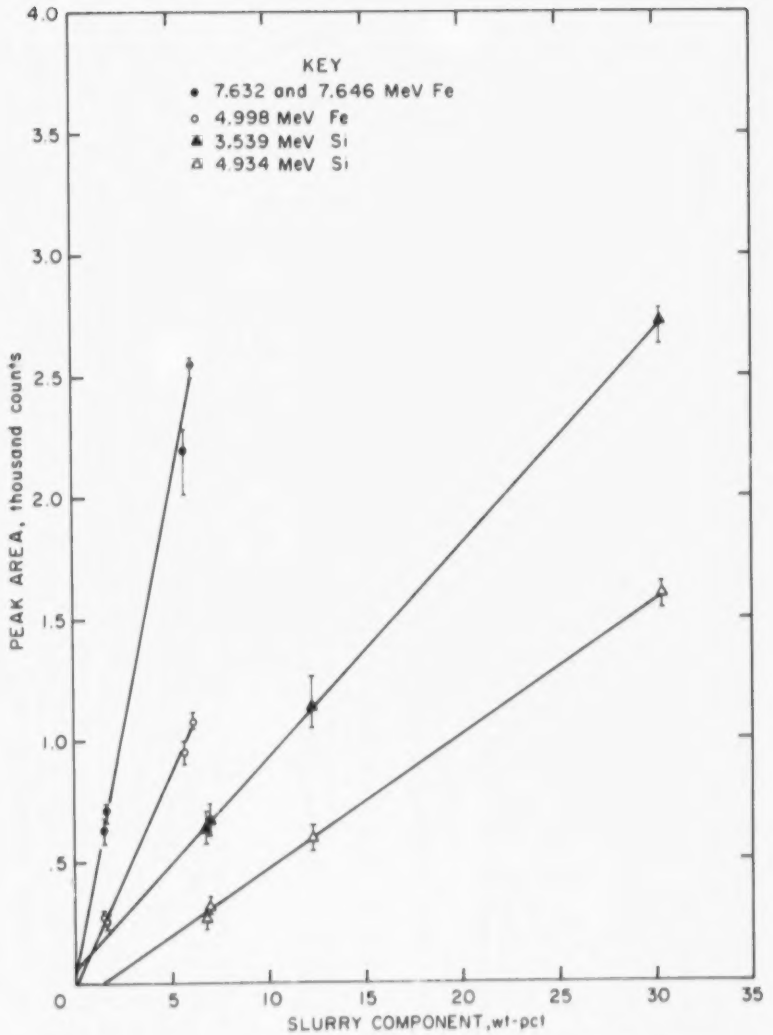

FIGURE 14. - Measurements of the major iron and silicon responses as a function of composition of the flotation slurries.

Error bars indicate the range in peak counts obtained during the course of at least five replicate observations. The variation in the number of counts are related to

1. Variation in neutron flux in the slurry.

2. Variations due to nuclear counting statistics.

3. Inadequate peak resolution due to equipment restriction (FWHM less than five channels).

4. Low peak signals imposed on a high background continuum.

5. Method of digital peak evaluation.

6. Nuclear transmutations due to long-term irradiation during replicated runs.

In addition to the above causes of variation in the peak area measurement, there is also a relationship between slurry density and the peak area measurement. The counts in the peak are proportional to the number of neutron captures that occur and are a measure of the number of nuclei of the element in the whole process slurry. For example, if the percent solids of a slurry is varied, but the concentration of a given element in the solids remain the same, the peak responses will increase when the percent solids are increased because the number of capture reactions will increase with the increasing number of target nuclei.

The range of count variation in any peak measurement results in a proportional variation in the range of the determination of the amount of the component in the slurry. Extrapolation of the error bars back to the linear regression lines in figure 14 will give an estimate of the range of the variation of the slurry component determination. This extrapolation method indicated that the silica analyses, for the replicate tests using the 4.934-MeV silicon peak gave a variation of ±1.0 percent from the wet chemical analysis of the silica in the slurry. The iron analyses, using the 4.998-MeV iron second escape peak had a variation of ±0.25 percent from the wet chemical analysis of the weight-percent iron in the slurry. The effect of this variation is shown in the ranges of iron and silica analyses of the solids in the pilot plant slurries reported in table 5. The data in table 5 were obtained as shown in the following example:

> In slurry S-6, which contains 40.3 percent solids, the expected variation from the wet chemical analysis of the iron in the total slurry is ±0.25 percent and results in a variation in the solids iron analysis of ±0.63 percent, that is, $\frac{0.25}{40.3/100} = 0.63$.

If the percent solids of a homogeneous slurry is increased, that is, an increase in the number of target nuclei in the sample, the reliability of the peak measurement increases. At the same percent solids, the iron measurements

have less variation than the silica measurements. The difference in variations is related to the difference in their thermal neutron capture cross section ($^{\sigma}Fe$ = 2.62 barns; $^{\sigma}Si$ = 0.16 barn) which controls the probability of the occurrence of the capture reactions. These results are in agreement with equation 8, which relates target density and capture cross section with the number of interactions.

TABLE 5. - Effect of slurry density on quantitative determinations[1]

Slurry stream	Amount of component in solids, percent		Slurry density, percent solids
	Iron	Silica	
S-2...	36.6 ± 1.60	43.8 ± 6.39	15.6
S-3...	10.4 ± 1.71	82.9 ± 6.80	14.7
S-4...	17.2 ± 2.66	72.8 ± 10.60	9.4
S-6...	14.9 ± .63	75.3 ± 2.48	40.3

[1]Source size was 32 μg.

CONCLUSIONS

Thermal neutron capture-gamma ray analysis is an effective method for monitoring the iron in beneficiation process slurries. The best quantitative determination of iron was obtained in slurries with a high solids content. The silicon response was adequate for control purposes when employing high silica process stream such as tailing slurries; but under the condition evaluated, this response could not be used for grade control. Since the tests on pilot plant slurries were completed with a 32-μg source with a neutron yield of 0.74×10^{8} neutrons per second, an increased source size would improve the sensitivity and accuracy of measurements. Improvements in the computer evaluation of the spectrum data and refinement of the replication method should also improve the precision of the measurements of peak areas and the resultant determination of the slurry components.

The use of the thermal neutron capture-gamma ray analysis method as an on-line analyzer has the following advantages:

1. Multielement analysis capability.

2. Simplified sampling by measuring the bulk stream.

3. Minimal formation of radioactive products.

4. Analysis times that are independent of the half-life of activation products.

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APPENDIX A.--DESCRIPTION OF SPECIAL SOFTWARE AND HARDWARE TO SUPPORT THE HP COMPUTER AND MULTICHANNEL ANALYZER LINKAGE

To properly evaluate thermal neutron capture-gamma ray spectrum data, computer processing is a necessity. Capture gamma ray spectra are extremely complex and require considerable numerical evaluation to extract the proper information from a large amount of raw data.

Computer techniques have been applied to the evaluation of ordinary activation analysis spectra for some time, and hardware interfaces existed to allow the transfer of activation data to the computer for evaluation. The ordinary activation data evaluation methods were not immediately applicable to the evaluation of thermal neutron capture-gamma ray data. In activation analysis several hours are usually required to accumulate a single simple spectrum, thus it is possible to take considerable time between accumulations to evaluate a single spectrum, or to store the spectrum on hard copy (that is, paper tape or cards) for later evaluation. In the Bureau application of thermal neutron capture-gamma ray analysis, several complex spectra would be accumulated within a short time period; therefore, there is need for rapid transfer, storage, and evaluation of the spectral data. To accomplish these operations on the available hardware, it was necessary to modify the existing computer system operating software and to write additional supporting system software. The new system support package was designed to allow for the transfer of data between the MCA, the computer, and the mass storage unit (a moving head disc), as well as to provide for the operation of MCA function controls by the computer. Function control and data transfer are initiated through simple Fortran program statements, subroutine calls, or keyboard instructions.

The flowchart in figure A-1 shows the relationship between the central processing unit (CPU), the disc operation system (DOS), the system library, and the MCA input/output (I/O). The modifications that were developed to allow for the operation of the MCA within a DOS environment are noted on the shaded blocks on the flowchart. The following is a detailed description of the modifications and the requirements for their use.

Use of DOS-M/MCA/FORTRAN Library

The library software title .MCA (DOS-M/MCA/FORTRAN library), the associated drivers, and support utility routines, provide the FORTRAN programming capability, in a DOS-M environment, of the HP 5402B multichannel analyzer, in substitution for the HP Instrument Basic System. While MCA data transfer and function control are possible with HP Instrument Basic System, the disc mass storage capability was not available. The use of FORTRAN and DOS allows both expanded program capability and spectrum file storage not available in basic.

Description and Operation

The hardware requirements for this system are defined in table A-1. The DOS-M/MCA/FORTRAN library and associated software as defined in table A-2 contain both library routines and I/O drivers that are made part of the DOS-M operating system at the time of system generation. The software routines

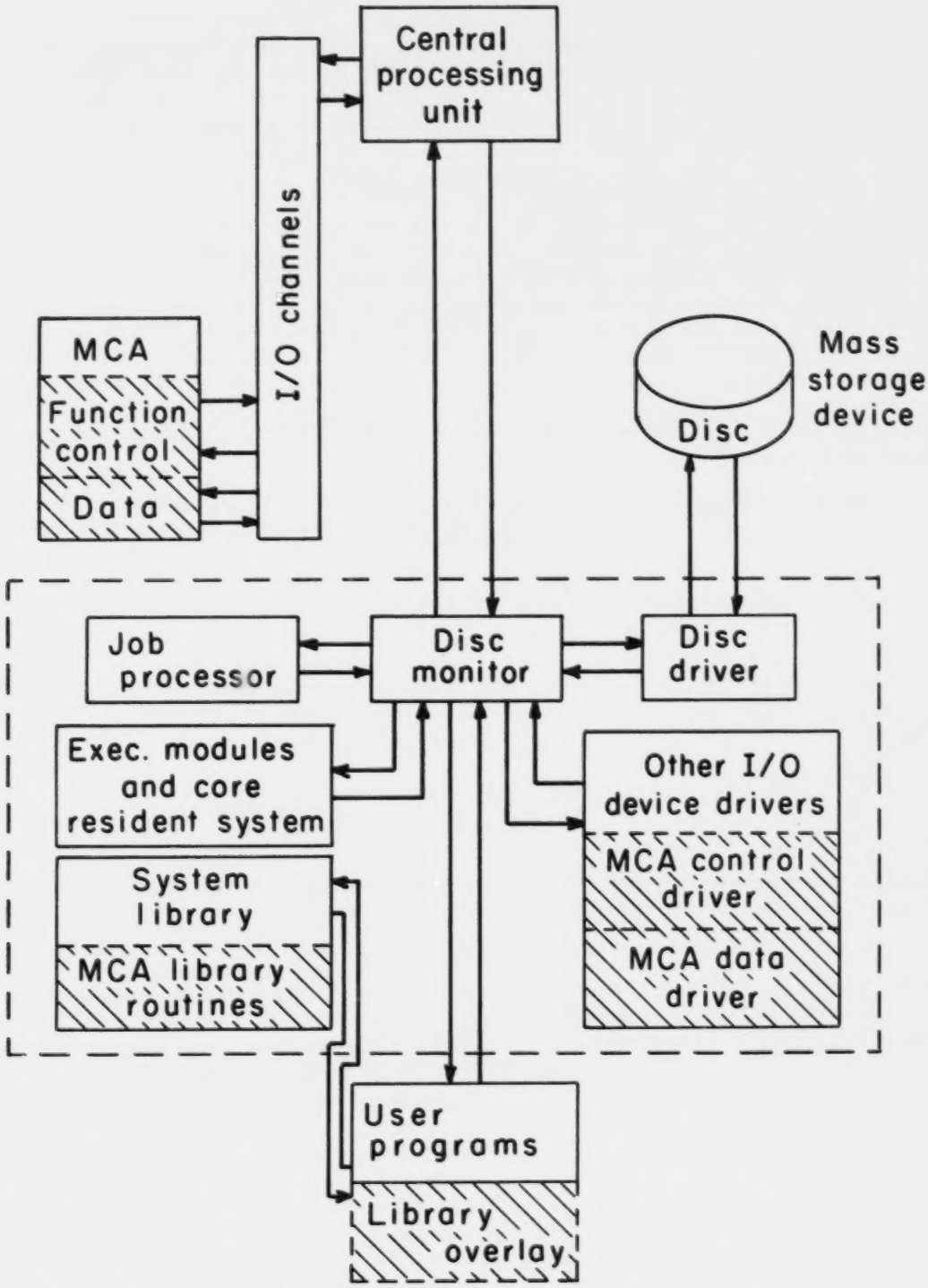

FIGURE A-1. - Flowchart for MCA modifications to DOS-M operating system.

service the FORTRAN call statements listed in tables A-3 and A-4 whenever any of the calls are included in a FORTRAN language (or assembler) program. The routines do not change the operation of FORTRAN in any way other than adding the MCA and data transfer control service functions. For proper operation, the listed hardware items and the listed software items must be part of the system. The MCA disc utility package is a set of software subroutines and programs that use .MCA to service the MCA. FORTRAN listing of the programs and subroutines are given in appendix D. The library MCA was configured for a 1,024-channel MCA, with option to use the library with a larger MCA by changing the source statement 434, such that, if the MCA memory is "4K" then line 434 should be LDA = D-2, and if the MCA memory is "8K", then line 434 should be CCA. The DOS-M Exec Calls are set up for logical units so that any MCA error messages are output to teletype or system terminal, which is logical unit 1, by source statement line 509 CW2 OCT 1. The MCA control function-logical unit number is established by source statement lines 211 and 212. In the present usage, this unit is established as logical unit 7, but can be changed by settling CONW1 and CONW2 equal to OCT 00010X, where "X" is the new logical unit number.

TABLE A-1. - Hardware items required for the DOS-M/MCA/FORTRAN library

Item	Type
HP 5402B.....	Multichannel Analyzer System and Computer.
HP 7900.....	Moving Head Disc System.
HP 10610A.....	HP MCA Remote Function Card.
HP 12566B.....	Microcircuit Interface Card.
HP 12554B.....	16-Bit Duplex Interface Card.

TABLE A-2. - Software items required for the DOS-M/MCA/FORTRAN library

Item	Type
.MCA.....	DOS-M/MCA/FORTRAN library.
BDECB.....	Library routine for converting data to binary coded decimal for input to MCA through remote function card.
DVR-54.....	HP supplied driver for serial I/O of data through MCA interface and 12554 duplex interface (HP 05402-98004).
DVR-55.....	DOS-M driver for MCA control and data transfer through MCA remote function card under program control.
MCA disc utility package.	Series of subroutines and programs to control transfer of MCA data to and from disc files.

TABLE A-3. - MCA control commands

Equivalent MCA control settings	Control command (MCA function switch must be set to external)	Notes
STOP button pressed.....	CALL STOPM.....	Stops MCA operation.
START button pressed.....	CALL START.....	Initiate MCA operation for last control function loaded into remote function card.
FUNCTION = ERASE (A).....	CALL ERASE.....	Erases MCA memory selected by group selection switch A.
FUNCTION = Accumulate; Start pressed.	CALL ACCUM.....	Initiates accumulation mode.
FUNCTION = Read I/O; Device selector = display; Start pressed.	CALL DISPB.....	For display group B.
FUNCTION = Display; Start pressed.	CALL DISPF.....	For display of full memory.
FUNCTION = Read I/O; Device selector = Tape punch/type; Start pressed.	CALL MCASO.....	For analyzer serial output.[1]
FUNCTION = Read I/O; Device selector = TAPE READER; Start pressed.	CALL MCASI.....	For analyzer serial input.[2]
FUNCTION = Transfer A to B; Start pressed.	CALL XFR.....	Transfer memory contacts of group A to group B channels.

[1]DVR-55 handles only the control function word, then DVR-55 handles data transfer through FORTRAN write statements. See comments in DVR-55 lines 38-44 and the example in program DTMCA (the 4 lines following call MCASO).

[2]Same as footnote 1, except uses FORTRAN read statements; example in Program DINT8 (the 4 lines following call MCASI).

TABLE A-4. - Data transfer control commands

Action	Command	Notes
Write a word into MCA memory at a selected location, from the computer.	CALL PUTDV (IA,D): IA = MCA memory address; D = Data team term.	IA must be an integer value; D must be a real number.
Read a word from a selected MCA memory location into the computer.	CALL GETDV (IA=V): IA = MCA memory address term; V = FORTRAN variable designated to receive data from MCA.	IA must be an integer value; V must be a real variable.
MCA status check.....	CALL MCAST (I): I = FORTRAN integer variable designed to receive status check value. This command returns a "1" if in operation light is on; a "Ø" if light is off.	
Read a spectrum of 1,024 words from MCA and store in a disc file.	CALL DSTOR (Lu,V): Lu = Logical unit from which file name will be read; V = Array of 1,024 real words (must be dimensioned in program).	In keyboard mode of DOS-M same thing can be accomplished with :PR, DTMCA.
Retrieve a spectrum from a disc file and read it into MCA.	CALL DTRET (Lu,V)...	In keyboard mode :PR DINT8.
Retrieve a spectrum from disc file and read it into the computer.	CALL DOUTC.....	
Retrieve a spectrum from disc file and write it on TTY.	Keyboard mode only :PR, DOUT1.	This would be possible to do from program mode by changing DOUT1 from a program into a subroutine.

When the MCA function switch is set to "external" the programed MCA control commands, as listed in table A-3 will cause MCA operation responses that duplicate the manual operation of the MCA's front panel controls. The data transfer control commands listed in table A-4 used in conjunction with MCA disc utility routines, exercise the two-way data transfer capabilities of the 5402A system. The status check command is used to return the MCA status information to the program. Paper tape I/O could be provided by means of computer transfer to MCA, and from the programed paper tape. An assembler listing of MCA, the DOS-M/MCA/FORTRAN LIBRARY is given in appendix B.

DOS-M Driver DVR-55

The function of driver DVR-55 is to operate the MCA functions, through the MCA remote function interface, under program control in a DOS-M system. The driver determines the type of control function requested, checks the request to make sure it is legal, initializes the request, determines when the request is completed, and prepares the system for the next request. Computer flowcharts showing the logic of the Initiation Section for DVR-55 is shown in figure A-2, while the Completion Section for DVR-55 is shown in figure A-3. An assembler listing of the DOS-M MCA remote function control driver, is given in appendix C.

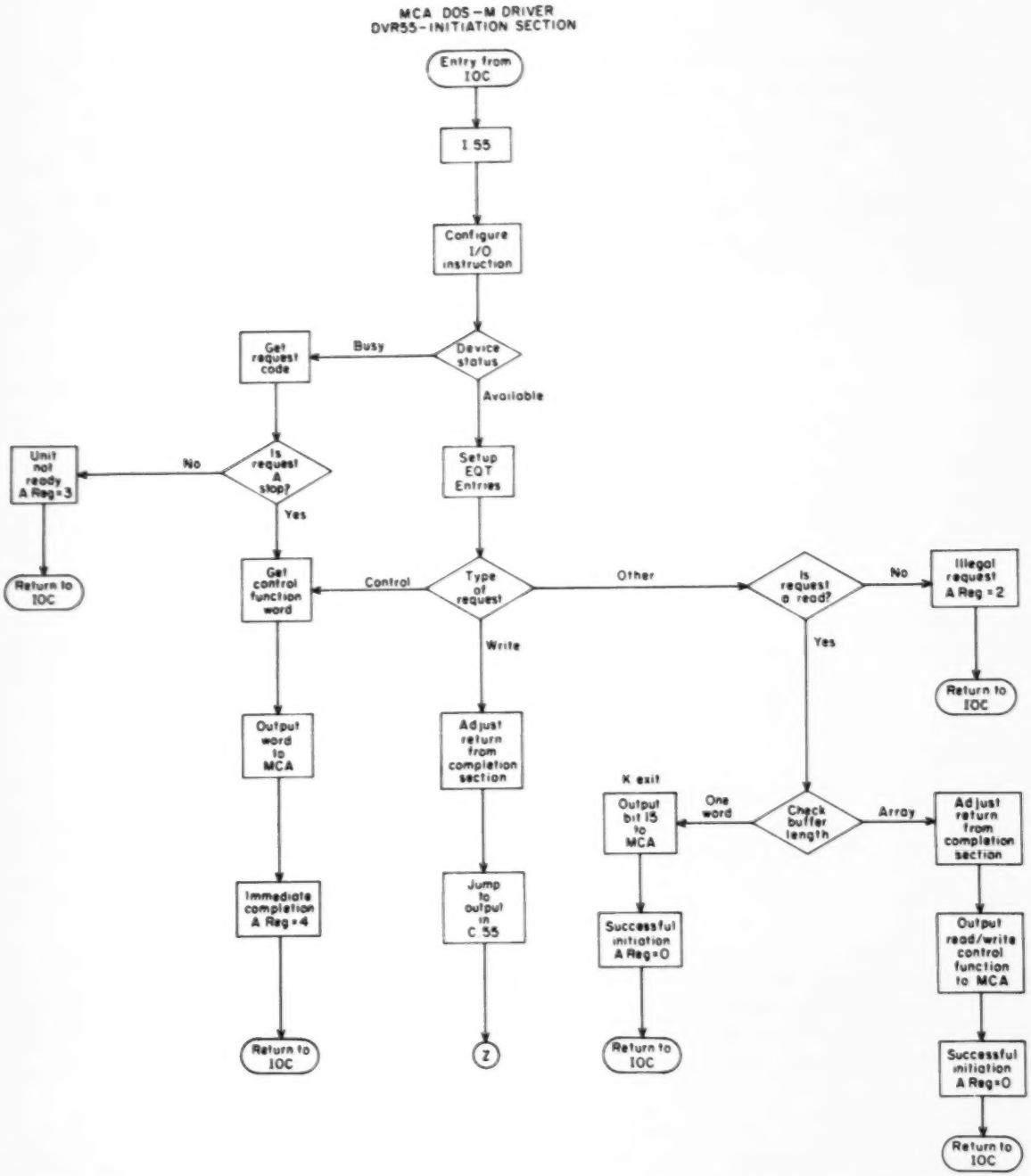

FIGURE A-2. - Computer flowchart for the logic operations of the initiation section of DVR-55.

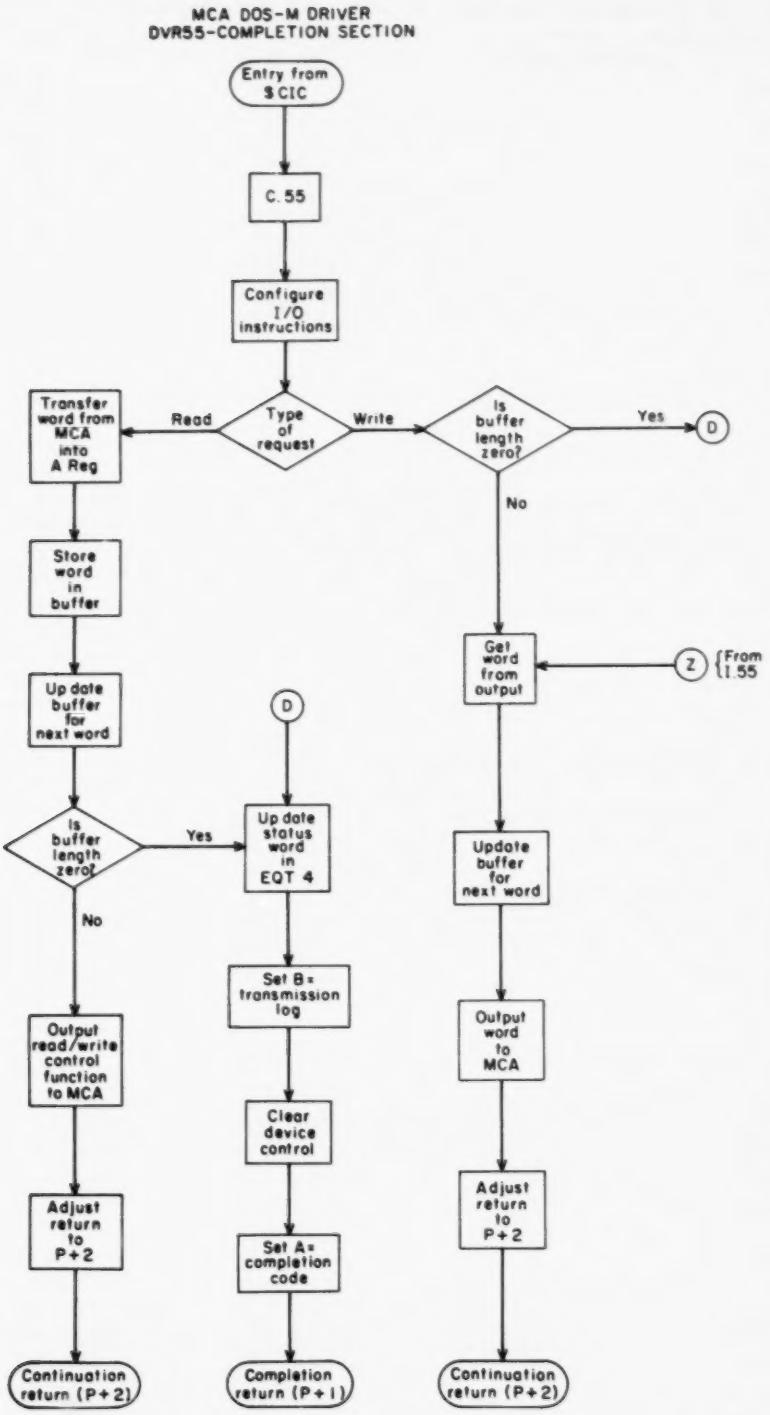

FIGURE A-3. - Computer flowchart for the logic operations of the completion section of DVR-55.

APPENDIX B.--ASSEMBLER LISTING OF .MCA, THE DOS-M/MCA FORTRAN LIBRARY

```
0001                    ASMB,L,B,T
EXEC   X 000001
.ENTR  X 000002
.DLD   X 000003
.DST   X 000004
IFIX   X 000005
FLOAT  X 000006
@DBIN  X 000007
@BDEC  X 000010
PUTDV  R 000227
GETDV  R 000361
ERASE  R 000000
ACCUM  R 000016
DISPB  R 000032
MCASO  R 000046
MCASI  R 000062
DISPF  R 000076
XFR    R 000112
WAIT   R 000130
MCAST  R 000165
START  R 000154
STOPM  R 000144
A        000000
B        000001
STOP   R 000144
ON?    R 000164
RCOD1  R 000204
RCOD2  R 000205
RCOD3  R 000206
OWORD  R 000207
INOPL  R 000210
BIT15  R 000211
CONW1  R 000212
CONW2  R 000213
ERAS   R 000214
ACCU   R 000215
RDCRT  R 000216
PUNC   R 000217
TPRD   R 000220
DISPY  R 000221
TRAN   R 000222
SMCAS  R 000223
SMCAP  R 000224
WADR   R 000225
WDTA   R 000226
WRITE  R 000227
WLOOP  R 000322
WCOUN  R 000341
TINWD  R 000342
INWRD  R 000343
WDIGT  R 000354
AINWD  R 000355
LPCNT  R 000356
RADR   R 000357
RDTA   R 000360
READ   R 000361
BLOPW  R 000457
OPWRD  R 000460
MADRS  R 000470
MEMSZ  R 000471
FST    R 000472
T1     R 000474
T2     R 000475
T3     R 000476
T4     R 000477
T5     R 000500
.2     R 000501
.15    R 000502
.32    R 000503
MADSS  R 000504
ERRA   R 000532
M8192  R 000534
RDIN   R 000535
RDOUT  R 000536
ADR    R 000537
RDWRT  R 000540
ERR1   R 000541
ERR2   R 000551
ERR3   R 000561
ERR4   R 000571
RCODE  R 000601
CW2    R 000602
MSG1   R 000603
MSG2   R 000606
MSG3   R 000611
MSG4   R 000614
EBUFL  R 000617
CONV   R 000620
.FMP   X 000011
.FAD   X 000012
BCD6   R 000640
LP1    R 000656
LP2    R 000666
ERRB   R 000702
** NO ERRORS*
```

```
0001                ASMB,L,B,T
0003*    ************************************************************
0004*    *      TWIN CITIES METALLURGY RESEARCH CENTER              *
0005*    *                  BUREAU OF MINES                         *
0006*    *            U.S. DEPT. OF THE INTERIOR                    *
0007*    *                                                          *
0008*    *  PROGRAM NAME - .MCA                                     *
0009*    *  DESCRIPTION  - MCA FORTRAN LIBRARY FOR USE WITH         *
0010*    *                 DOS-M OPERATION OF THE 5402B SYSTEM      *
0011*    *                 THRU A 10610A REMOTE FUNCTION INTER-     *
0012*    *                 FACE CARD. THIS CARD REQUIRES THAT A     *
0013*    *                 12566B MICROCUIT INTERFACE CARD BE       *
0014*    *                 INSTALLED & THE USE OF AUTHOR'S DVR55    *
0015*    *                 THE SERIAL IN-OUT FUNCTIONS OPERATE      *
0016*    *                 THRU A 12554A 16-BIT DUPLEX CARD AND     *
0017*    *                 REQUIRES HP DVR54 #05402-98004.          *
0018*    *                                                          *
0019*    *  AUTHOR       - FRANKLIN B.W. WOODBURY(612-725-4645)     *
0020*    *                                                          *
0021*    *  THIS REVISION OF HP MCA/FORTRAN LIBRARY #05402-98002    *
0022*    *  WAS DEVELOPED AS PART OF THE AEC CALIFORNIUM-252        *
0023*    *  MARKET EVALUATION PROGRAM,  UNDER INTERAGENCY           *
0024*    *  AGREEMENT NUMBER AT(38-1)-747.                          *
0025*    ************************************************************
0026*
0027* ### NOTE ###  SOURCE STATEMENT NO. 381 MUST BE ADJUSTED
0028* FOR MEMORY SIZE OF MCA, SEE INSTRUCTIONS IN STATEMENT #366
0029*
0030  00000                 NAM .MCA,7
0031                        EXT EXEC,.ENTR,.DLD,.DST,IFIX,FLOAT
0032                        EXT @DBIN,@BDEC
0033                        ENT PUTDV,GETDV,ERASE,ACCUM,DISPB
0034                        ENT MCASO,MCASI,DISPF,XFR,WAIT,MCAST
0035                        ENT START,STOPM
0036*
0037  00000          A      EQU 0
0038  00001          B      EQU 1
0039                        SUP
0040*
0041  00000 000000  ERASE NOP
0042  00001 016144R       JSB STOP        HALT THE MCA.
0043  00002 000003R       DEF *+1
0044  00003 016001X       JSB EXEC        OUTPUT
0045  00004 000010R       DEF *+4              THE
0046  00005 000206R       DEF PCOD3              ERASE
0047  00006 000212R       DEF CONW1                 CONTROL
0048  00007 000214R       DEF ERAS                     FUNCTION.
0049  00010 016154R       JSB START       START THE MCA.
0050  00011 000012R       DEF *+1
0051  00012 016130R       JSB WAIT        WAIT UNTIL ERASE
0052  00013 000014R       DEF *+1             IS FINISHED.
0053  00014 162000R       LDA ERASE,I
0054  00015 124000        JMP A,I
0055*
```

```
0057*
0058  00016 000000  ACCUM NOP
0059  00017 016144R       JSB STOP
0060  00020 000021R       DEF *+1
0061  00021 016001X       JSB EXEC       OUTPUT
0062  00022 000026R       DEF *+4             THE
0063  00023 000206R       DEF RCOD3             ACCUMULATE
0064  00024 000212R       DEF CONW1                CONTROL
0065  00025 000215R       DEF ACCU                     FUNCTION.
0066  00026 016154R       JSB START
0067  00027 000030R       DEF *+1
0068  00030 162016R       LDA ACCUM,I
0069  00031 124000        JMP A,I
0070*
0071*
0072  00032 000000  DISPB NOP
0073  00033 016144R       JSB STOP
0074  00034 000035R       DEF *+1
0075  00035 016001X       JSB EXEC       OUTPUT
0076  00036 000042R       DEF *+4             THE
0077  00037 000206R       DEF RCOD3             GROUP 'B'
0078  00040 000212R       DEF CONW1                DISPLAY
0079  00041 000216R       DEF RDCRT                   CONTROL
0080  00042 016154R       JSB START                       FUNCTION.
0081  00043 000044R       DEF *+1
0082  00044 162032R       LDA DISPB,I
0083  00045 124000        JMP A,I
0084*
0085*
0086  00046 000000  MCASO NOP
0087  00047 016144R       JSB STOP
0088  00050 000051R       DEF *+1
0089  00051 016001X       JSB EXEC       OUTPUT
0090  00052 000056R       DEF *+4             THE
0091  00053 000206R       DEF RCOD3             MCA SERIAL OUTPUT
0092  00054 000212R       DEF CONW1                CONTROL
0093  00055 000217R       DEF PUNC                       FUNCTION.
0094  00056 016154R       JSB START
0095  00057 000060R       DEF *+1
0096  00060 162046R       LDA MCASO,I
0097  00061 124000        JMP A,I
0098*
0099*
0100  00062 000000  MCASI NOP
0101  00063 016144R       JSB STOP
0102  00064 000065R       DEF *+1
0103  00065 016001X       JSB EXEC       OUTPUT
0104  00066 000072R       DEF *+4             THE
0105  00067 000206R       DEF RCOD3             MCA SERIAL INPUT
0106  00070 000212R       DEF CONW1                CONTROL
0107  00071 000220R       DEF TPRD                    FUNCTION.
0108  00072 016154R       JSB START
0109  00073 000074R       DEF *+1
0110  00074 162062R       LDA MCASI,I
0111  00075 124000        JMP A,I
0112*
```

```
0113*
0114  00076 000000  DISPF NOP
0115  00077 016144R       JSB STOP
0116  00100 000101R       DEF *+1
0117  00101 016001X       JSB EXEC       OUTPUT
0118  00102 000106R       DEF *+4             THE
0119  00103 000206R       DEF RCOD3              FULL SPECTRUM
0120  00104 000212R       DEF CONW1                    DISPLAY
0121  00105 000221R       DEF DISPY                      CONTROL
0122  00106 016154R       JSB START                         FUNCTION.
0123  00107 000110R       DEF *+1
0124  00110 162076R       LDA DISPF,I
0125  00111 124000        JMP A,I
0126*
0127*
0128  00112 000000  XFR   NOP
0129  00113 016144R       JSB STOP
0130  00114 000115R       DEF *+1
0131  00115 016001X       JSB EXEC       OUTPUT
0132  00116 000122R       DEF *+4             THE
0133  00117 000206R       DEF RCOD3             'A' TO 'B' TRANSFER
0134  00120 000212R       DEF CONW1                   CONTROL
0135  00121 000222R       DEF TRAN                         FUNCTION.
0136  00122 016154R       JSB START
0137  00123 000124R       DEF *+1
0138  00124 016130R       JSB WAIT
0139  00125 000126R       DEF *+1
0140  00126 162112R       LDA XFR,I
0141  00127 124000        JMP A,I
0142*
0143*
0144  00130 000000  WAIT  NOP
0145  00131 016001X       JSB EXEC       IS
0146  00132 000137R       DEF *+5           THE
0147  00133 000204R       DEF RCOD1              MCA
0148  00134 000213R       DEF CONW2                  IN-OPERATION
0149  00135 000210R       DEF INOPL                        LIGHT ON?
0150  00136 000207R       DEF OWORD
0151  00137 062210R       LDA INOPL
0152  00140 002021        SSA,RSS
0153  00141 026131R       JMP *-8              YES,KEEP CHECKING
0154  00142 162130R       LDA WAIT,I
0155  00143 124000        JMP A,I              NO, RETURN
0156*
0157*
0158  00144         STOPM BSS 0
0159  00144 000000  STOP  NOP
0160  00145 016001X       JSB EXEC       OUTPUT
0161  00146 000152R       DEF *+4             THE
0162  00147 000206R       DEF RCOD3             "STOP"
0163  00150 000212R       DEF CONW1                CONTROL
0164  00151 000224R       DEF SMCAP                      FUNCTION.
0165  00152 162144R       LDA STOP,I
0166  00153 124000        JMP A,I
0167*
0168*
```

```
0169*
0170   00154 000000  START NOP
0171   00155 016001X        JSB EXEC       OUTPUT
0172   00156 000162R        DEF *+4             THE
0173   00157 000206R        DEF RCOD3              "START"
0174   00160 000212R        DEF CONW1                   CONTROL
0175   00161 000223R        DEF SMCAS                        FUNCTION.
0176   00162 162154R        LDA START,I
0177   00163 124000         JMP A,I
0178*
0179*
0180*        IN OPERATION STATUS CHECK
0181*
0182* THIS SUBROUTINE CHECKS THE STATUS OF THE MCA I/O CARD FOR THE
0183* STATUS OF THE REMOTE FUNCTION INTERFACE CARD; AND RETURNS
0184* A "1" WHEN UNIT IS ON, OR A "0" WHEN UNIT IS OFF AND AVAILABLE.
0185*
0186*
0187   00164 000164R ON?   DEF *
0188   00165 000000  MCAST NOP
0189   00166 016002X        JSB .ENTR      RETRIEVE AND CHECK
0190   00167 000164R        DEF ON?             PARAMETER ADDRESS
0191   00170 016001X        JSB EXEC
0192   00171 000176R        DEF *+5        IS
0193   00172 000204R        DEF RCOD1        THE
0194   00173 000213R        DEF CONW2          MCA
0195   00174 000210R        DEF INOPL            IN-OPERATION
0196   00175 000207R        DEF OWORD                LIGHT ON?
0197   00176 062210R        LDA INOPL
0198   00177 006400         CLB
0199   00200 002021         SSA,RSS
0200   00201 006004         INB
0201   00202 176164R        STB ON?,I
0202   00203 126165R        JMP MCAST,I
0203*
0204*
0205   00204 000001  RCOD1 DEC 1          REQUEST CODE FOR 'I/O READ'
0206   00205 000002  RCOD2 DEC 2          REQUEST CODE FOR 'I/O WRITE'
0207   00206 000003  RCOD3 DEC 3          REQUEST CODE FOR 'I/O CONTROL'
0208   00207 000001  OWORD DEC 1          A ONE WORD BUFFER
0209   00210 000000  INOPL BSS 1          IN OPERATION LIGHT
0210   00211 100000  BIT15 OCT 100000     STATUS BIT
0211   00212 000107  CONW1 OCT 000107     CONTROL WORD,LU7,WITH WAIT
0212   00213 000107  CONW2 OCT 000107     CONTROL WORD,LU7,WITH WAIT
0213   00214 040001  ERAS  OCT 40001      MCA FUNCTION CONTROL-ERASE
0214   00215 040002  ACCU  OCT 40002      MCA FUNCTION CONTROL-ACCUMULATE
0215   00216 040003  PDCRT OCT 40003      MCA FUNCTION CONTROL-DISPLAY'B'
0216   00217 040005  PUNC  OCT 40005      MCA FUNCTION CONTROL-SERIAL OUT
0217   00220 040006  TPRD  OCT 40006      MCA FUNCTION CONTROL-SERIAL IN
0218   00221 040007  DISPY OCT 40007      MCA FUNCTION CONTROL-DISPLAY FUL
0219   00222 040010  TRAN  OCT 40010      MCA FUNCTION CONTROL-TRANSFER
0220   00223 000000  SMCAS OCT 000000     MCA FUNCTION CONTROL-START MCA
0221   00224 000001  SMCAP OCT 000001     MCA FUNCTION CONTROL-STOP MCA
0222*
0223*
```

```
0225*
0226*          READ WORD IN/OUT OF MCA
0227*
0228* THESE SUBROUTINES READ A SINGLE WORD INTO OR OUT OF THE MCA
0229*
0230* TO READ A WORD INTO THE MCA USE --- CALL GETDV(IA,C)
0231* TO WRITE A WORD INTO THE MCA USE -- CALL PUTDV(IA,D)
0232*
0233*       WHERE:     IA = MCA CHANNEL ADDRESS OF WORD (INTEGER VALUE)
0234*                   C = COUNTS STORED IN THE ADDRESSED CHANNEL
0235*                   D = DATA TO BE STORED IN MCA
0236*
0237*
0238  00225 000225R WADR  DEF *
0239  00226 000226R WDTA  DEF *
0240  00227         PUTDV BSS 0
0241  00227 000000  WRITE NOP
0242  00230 016002X       JSB .ENTR     RETRIEVE AND CHECK
0243  00231 000225R       DEF WADR           PARAMETER ADDRESS
0244  00232 062503R       LDA .32               ADD ASCII SPACE.
0245  00233 042540R       ADA RDWRT                TO CONTROL FUNCTION.
0246  00234 072343R       STA INWRD     SAVE IN ARRAY
0247  00235 016003X       JSB .DLD      GET DATA VALUE
0248  00236 100226R       DEF WDTA,I
0249  00237 016640R       JSB BCD6      CONVERT TO BCD FORMAT
0250  00240 072476R       STA T3        SAVE DIGITS D4,D3,D2,D1
0251  00241 062474R       LDA T1        GET DIGIT D6
0252  00242 042540R       ADA RDWRT          ADD CONTROL FUNCTION
0253  00243 072344R       STA INWRD+1              AND SAVE
0254  00244 062475R       LDA T2        GET DIGIT D5
0255  00245 042540R       ADA RDWRT          ADD CONTROL FUNCTION
0256  00246 072345R       STA INWRD+2              AND SAVE
0257  00247 062476R       LDA T3        GET D4,D3,D2,D1
0258  00250 001700        ALF                ROTATE,
0259  00251 072476R       STA T3                SAVE D3,D2,D1
0260  00252 012502R       AND .15       ISOLATE D4
0261  00253 042540R       ADA RDWRT          ADD CONTROL FUNCTION
0262  00254 072346R       STA INWRD+3              AND SAVE
0263  00255 062476R       LDA T3        GET D3,D2,D1
0264  00256 001700        ALF                ROTATE,
0265  00257 072476R       STA T3                SAVE D2,D1
0266  00260 012502R       AND .15       ISOLATE D3
0267  00261 042540R       ADA RDWRT          ADD CONTROL FUNCTION
0268  00262 072347R       STA INWRD+4              AND SAVE
0269  00263 062476R       LDA T3        GET D2,D1
0270  00264 001700        ALF                ROTATE,
0271  00265 072476R       STA T3                SAVE D1
0272  00266 012502R       AND .15       ISOLATE D2
0273  00267 042540R       ADA RDWRT          ADD CONTROL FUNCTION
0274  00270 072350R       STA INWRD+5              AND SAVE
0275  00271 062476R       LDA T3        GET D1
0276  00272 001700        ALF                ROTATE
0277  00273 072476R       STA T3        ISOLATE D1
0278  00274 012502R       AND .15            ADD CONTROL FUNCTION
0279  00275 042540R       ADA RDWRT             AND
0280  00276 072351R       STA INWRD+6              SAVE.
```

```
0281  00277 002400          CLA               SET UP ZERO
0282  00300 042540R         ADA RDWRT               ADD CONTROL FUNCTION
0283  00301 072352R         STA INWRD+7       SAVE
0284  00302 072353R         STA INWRD+8       SAVE.
0285  00303 016144R         JSB STOP          HALT MCA
0286  00304 000305R         DEF *+1
0287  00305 016001X         JSB EXEC          OUTPUT
0288  00306 000312R         DEF *+4                THE "READ IN"
0289  00307 000206R         DEF RCOD3                   CONTROL
0290  00310 000212R         DEF CONW1                      FUNCTION.
0291  00311 000535R         DEF RDIN
0292  00312 166225R         LDB WADR,I        GET CHANNEL ADDRESS
0293  00313 016504R         JSB MADSS         ADJUST FOR MCA MEMORY SIZE
0294  00314 016154R         JSB START         START MCA
0295  00315 000316R         DEF *+1
0296  00316 062342R         LDA TINWD         GET BUFFER ADDRESS
0297  00317 072355R         STA AINWD              AND SAVE.
0298  00320 062341R         LDA WCOUN         GET WORD COUNT
0299  00321 072356R         STA LPCNT              SAVE
0300  00322 162355R WLOOP   LDA AINWD,I       GET WORD FROM TABLE
0301  00323 072354R         STA WDIGT              SAVE
0302  00324 016001X         JSB EXEC          OUTPUT
0303  00325 000332R         DEF *+5                THE
0304  00326 000205R         DEF RCOD2                 DIGIT
0305  00327 000213R         DEF CONW2                    TO
0306  00330 000354R         DEF WDIGT                     THE
0307  00331 000207R         DEF OWORD                           MCA.
0308  00332 036355R         ISZ AINWD         INCREMENT ADDRESS
0309  00333 000000          NOP
0310  00334 036356R         ISZ LPCNT         INCREMENT WORD COUNT
0311  00335 026322R         JMP WLOOP            IF NOT ZERO,REPEAT
0312  00336 016144R         JSB STOP             IF ZERO,CONTINUE TO NEXT
0313  00337 000340R         DEF *+1           HALT MCA.
0314  00340 126227R         JMP WRITE,I       RETURN.
0315*
0316*
0317*
0318  00341 177767  WCOUN DEC -9              WORD COUNT
0319  00342 000343R TINWD DEF INWRD           TABLE FOR INWORD ARRAY
0320  00343 000000  INWRD BSS 9               INWORD ARRAY
0321  00354 000000  WDIGT BSS 1               DIGIT WORD
0322  00355 000000  AINWD BSS 1               POINTER FOR TABLE
0323  00356 000000  LPCNT BSS 1               POINTER FOR WORD COUNT
0324*
0325*
0326*
0327*
```

```
0329*
0330   00357 000357R RADR   DEF *
0331   00360 000360R RDTA   DEF *
0332   00361         GETDV  BSS 0
0333   00361 000000  READ   NOP
0334   00362 016002X        JSB .ENTR      RETRIEVE AND CHECK
0335   00363 000357R        DEF RADR             PARAMETER ADDRESS
0336   00364 016144R        JSB STOP       HALT MCA
0337   00365 000366R        DEF *+1
0338   00366 016001X        JSB EXEC       OUTPUT
0339   00367 000373R        DEF *+4              THE "READ OUT"
0340   00370 000206R        DEF RCOD3                 CONTROL
0341   00371 000212R        DEF CONW1                   FUNCTION.
0342   00372 000536R        DEF RDOUT
0343   00373 166357R        LDB RADR,I     GET ADDRESS
0344   00374 016504R        JSB MADSS      ADJUST FOR MCA MEMORY SIZE.
0345   00375 016154R        JSB START      START MCA
0346   00376 000377R        DEF *+1
0347   00377 016001X        JSB EXEC       GET
0348   00400 000405R        DEF *+5           DATA
0349   00401 000204R        DEF RCOD1              FROM
0350   00402 000213R        DEF CONW2                 THE
0351   00403 000460R        DEF OPWRD                    MCA.
0352   00404 000457R        DEF BLOPW
0353   00405 056457R        CPB BLOPW      PROPER TRANSMISSION?
0354   00406 026410R        JMP *+2            YES, CONTINUE.
0355   00407 016551R        JSB ERR2           NO, ERROR.
0356   00410 062461R        LDA OPWRD+1    CHECK THE SECOND WORD.
0357   00411 012704R        AND =B77            IS IT AN
0358   00412 052503R        CPA .32                ASCII SPACE?
0359   00413 026416R        JMP *+3        YES, CONTINUE
0360   00414 016571R        JSB ERR4       NO, ERROR.
0361   00415 126361R        JMP READ,I     RETURN.
```

```
0363  00416 062462R        LDA OPWRD+2   ISOLATE D6 AND SAVE.
0364  00417 012502R        AND .15
0365  00420 001700         ALF
0366  00421 072476R        STA T3
0367  00422 062463R        LDA OPWRD+3   ISOLATE D5 AND SAVE.
0368  00423 012502R        AND .15
0369  00424 042476R        ADA T3
0370  00425 072476R        STA T3
0371  00426 062464R        LDA OPWRD+4   ISOLATE D4 AND SAVE.
0372  00427 012502R        AND .15
0373  00430 001700         ALF
0374  00431 072477R        STA T4
0375  00432 062465R        LDA OPWRD+5   ISOLATE D3 AND SAVE.
0376  00433 012502R        AND .15
0377  00434 042477R        ADA T4
0378  00435 001700         ALF
0379  00436 072477R        STA T4
0380  00437 062466R        LDA OPWRD+6   ISOLATE D2 AND SAVE.
0381  00440 012502R        AND .15
0382  00441 042477R        ADA T4
0383  00442 001700         ALF
0384  00443 072477R        STA T4
0385  00444 062467R        LDA OPWRD+7   ISOLATE D1 AND SAVE.
0386  00445 012502R        AND .15
0387  00446 042477R        ADA T4
0388  00447 072477R        STA T4
0389  00450 066476R        LDB T3        SET UP BCD WORD
0390  00451 016620R        JSB CONV      CONVERT TO FLOATING POINT.
0391  00452 016004X        JSB .DST      STORE.
0392  00453 100360R        DEF RDTA,I
0393  00454 016144R        JSB STOP      HALT MCA
0394  00455 000456R        DEF *+1
0395  00456 126361R        JMP READ,I    RETURN
0396*
0397*
0398*
0399  00457 000010  BLOPW DEF 8          BUFFER ADDRESS
0400  00460 000000  OPWRD BSS 8          BUFFER LENGTH
0401  00470 000000  MADRS BSS 1          MCA ADDRESS WORD
0402  00471 000000  MEMSZ BSS 1          MCA MEMORY SIZE WORD
0403  00472 000000  FST   BSS 2
0404  00474 000000  T1    BSS 1
0405  00475 000000  T2    BSS 1
0406  00476 000000  T3    BSS 1
0407  00477 000000  T4    BSS 1
0408  00500 000000  T5    BSS 1
0409  00501 000002  .2     DEC 2
0410  00502 000017  .15    DEC 15
0411  00503 000040  .32    DEC 32
0412*
0413*
```

```
0415*
0416*
0417*                    MCA WORD ADDRESS
0418*
0419* THIS SUBROUTINE SETS THE ADDRESS CONTROL WORD FOR THE ADDRESSED
0420* CHANNEL OF THE MCA, FROM WHICH, OR INTO WHICH THE DATA IS TAKEN.
0421*
0422*          THE VALUE  "MEMSZ"  IS THE MCA MEMORY SIZE.
0423*
0424*          "MEMSZ" WILL HAVE TO BE REVISED TO REFLECT THE MEMORY
0425*            SIZE OF THE MCA UNIT IN USE.  THE STATEMENT
0426*           "LDA =D-4" WILL HAVE TO BE CHANGED AS FOLLOWS:
0427*
0428*              IF MCA MEMORY IS '1K'         NO CHANGE NECESSARY
0429*              IF MCA MEMORY IS '4K'         LDA =D-2
0430*              IF MCA MEMORY IS '8K'         CCA
0431*
0432*
0433  00504 000000  MADSS NOP
0434  00505 062705R       LDA =D-4        MCA MEMORY SIZE(SEE NOTES ABOVE)
0435  00506 072471R       STA MEMSZ       SAVE
0436  00507 005300        RBR             POSITION
0437  00510 005200        RBL                 OF ADDRESS
0438  00511 034000        ISZ 0                   CORRECT?
0439  00512 026510R       JMP *-2         NO, REPEAT
0440  00513 076500R       STB T5          SAVE.
0441  00514 006020        SSB             NEGATIVE ADDRESS?
0442  00515 026532R       JMP ERRA            YES, ERROR.
0443  00516 046534R       ADB M8192           NO, SUBTRACT UPPER LIMIT.
0444  00517 006021        SSB,RSS         ABOVE UPPER LIMIT?
0445  00520 026532R       JMP ERRA             YES, ERROR.
0446  00521 062500R       LDA T5               NO, CONTINUE.
0447  00522 042537R       ADA ADR         ADD ADDRESS FUNCTION CONTROL.
0448  00523 072470R       STA MADRS               SAVE.
0449  00524 016001X       JSB EXEC        OUTPUT
0450  00525 000531R       DEF *+4              ADDRESS
0451  00526 000206R       DEF RCOD3                  TO
0452  00527 000212R       DEF CONW1                     THE
0453  00530 000470R       DEF MADRS                        MCA.
0454  00531 002001        RSS             UNCONDITIONAL SKIP.
0455  00532 016541R ERRA  JSB ERR1
0456  00533 126504R       JMP MADSS,I     RETURN
0457*
0458*
0459*
0460  00534 160000  M8192 DEC -8192       UPPER LIMIT MEMORY SIZE
0461  00535 040014  RDIN  OCT 40014       MCA CODE FOR "READ IN"
0462  00536 040013  RDOUT OCT 40013       MCA CODE FOR "READ OUT"
0463  00537 020000  ADR   OCT 20000       MCA CODE FOR ADDRESS"
0464  00540 060000  RDWRT OCT 60000       MCA CODE FOR "READ/WRITE"
0465*
0466*
```

```
0468*
0469**********ERROR ROUTINES**************************
0470*
0471*
0472*
0473  00541 000000  ERR1  NOP              PRINT   "***ARG"
0474  00542 016001X       JSB EXEC              TO INDICATE
0475  00543 000550R       DEF *+5                  AN ERROR IN
0476  00544 000601R       DEF RCODE                    A CALL
0477  00545 000602R       DEF CW2                        ARGUMENT.
0478  00546 000603R       DEF MSG1
0479  00547 000617R       DEF EBUFL
0480  00550 126541R       JMP ERR1,I
0481*
0482  00551 000000  ERR2  NOP
0483  00552 016001X       JSB EXEC          PRINT
0484  00553 000560R       DEF *+5              "***TSN"
0485  00554 000601R       DEF RCODE               TO INDICATE
0486  00555 000602R       DEF CW2                    DATA TRANSMISSION
0487  00556 000606R       DEF MSG2                         ERROR
0488  00557 000617R       DEF EBUFL
0489  00560 126551R       JMP ERR2,I
0490  00561 000000  ERR3  NOP              PRINT  "***FLG"
0491  00562 016001X       JSB EXEC              TO INDICATE
0492  00563 000570R       DEF *+5                  THAT THE MCA
0493  00564 000601R       DEF RCODE                    DID NOT RETURN
0494  00565 000602R       DEF CW2                        FLAG WHEN CALLED
0495  00566 000611R       DEF MSG3
0496  00567 000617R       DEF EBUFL
0497  00570 126561R       JMP ERR3,I
0498*
0499  00571 000000  ERR4  NOP              PRINT   "***MCA"
0500  00572 016001X       JSB EXEC              TO INDICATE
0501  00573 000600R       DEF *+5                  BAD DATA
0502  00574 000601R       DEF RCODE                    FROM THE
0503  00575 000602R       DEF CW2                        MCA.
0504  00576 000614R       DEF MSG4
0505  00577 000617R       DEF EBUFL
0506  00600 126571R       JMP ERR4,I
0507*
0508  00601 000002  RCODE DEC 2            REQUEST CODE FOR "I/O WRITE"
0509  00602 000001  CW2   OCT 1            CONTROL WORD FOR TTY OUTPUT
0510  00603 025052  MSG1  ASC 3,***ARG
0511  00606 025052  MSG2  ASC 3,***TSN
0512  00611 025052  MSG3  ASC 3,***FLG
0513  00614 025052  MSG4  ASC 3,***MCA
0514  00617 177772  EBUFL DEC -6         ERROR BUFFER LENGTH
0515*
0516*
0517*
0518*
0519*
```

```
0521*
0522*       BCD TO FLOATING POINT CONVERSION
0523*
0524* THIS CONVERSION RETURNS TO P+2 WITH THE FLOATING
0525* POINT NUMBER OR TO P+1 WHICH IS THE ERROR RETURN .
0526*
0527*            ENTRY:   B REG = -- -- D6 D5
0528*                     A REG = D4 D3 D2 D1
0529*             EXIT:   A REG = MSB
0530*                     B REG = LSB & EXPONENT
0531*
0532*
0533  00620 000000  CONV  NOP
0534  00621 016007X       JSB @DBIN
0535  00622 000066        CLE,ELA
0536  00623 005600        ELB
0537  00624 001300        RAR
0538  00625 076474R       STB T1
0539  00626 016006X       JSB FLOAT
0540  00627 104400        DST FST
0541  00631 062474R       LDA T1
0542  00632 016006X       JSB FLOAT
0543  00633 016011X       FMP =F32768.0
0544  00635 016012X       FAD FST
0545  00637 126620R       JMP CONV,I
0546*
0547*
```

```
0549*
0550*       FLOATING POINT TO BCD CONVERSION
0551*
0552* THIS CONVERSION RETURNS WITH A 6 DIGIT BCD NUMBER.
0553*
0554*              ENTRY:  A REG = MSB
0555*                      B REG = LSB & EXPONENT
0556*              EXIT:   A REG = D4 D3 D2 D1
0557*                        T2  = D5
0558*                        T1  = D6
0559*
0560*
0561  00640 000000  BCD6  NOP
0562  00641 002020        SSA
0563  00642 026702R       JMP ERRB
0564  00643 104400        DST FST
0565  00645 016012X       FAD =F-1000000.0
0566  00647 002021        SSA,RSS
0567  00650 026702R       JMP ERRB
0568  00651 002400        CLA
0569  00652 072474R       STA T1
0570  00653 072475R       STA T2
0571  00654 104200        DLD FST
0572  00656 016012X LP1   FAD =F-100000.0
0573  00660 002020        SSA
0574  00661 026664R       JMP *+3
0575  00662 036474R       ISZ T1
0576  00663 026656R       JMP LP1
0577  00664 016012X       FAD =F100000.0
0578  00666 016012X LP2   FAD =F-10000.0
0579  00670 002020        SSA
0580  00671 026674R       JMP *+3
0581  00672 036475R       ISZ T2
0582  00673 026666R       JMP LP2
0583  00674 016012X       FAD =F10000.0
0584  00676 016005X       JSB IFIX
0585  00677 006400        CLB
0586  00700 016010X       JSB $BDEC
0587  00701 002001        RSS
0588  00702 016541R ERRB  JSB ERR1
0589  00703 126640R       JMP BCD6,I
0590*
0591*
0592*
0593                      END
**  NO ERRORS*
```

```
0001                    ASMB,T,L,B
@DBIN R 000000
@BDEC R 000051
CONV1 R 000012
NEXT1 R 000032
MORE1 R 000035
DONE1 R 000040
EXIT1 R 000050
SIZE  R 000067
CONV  R 000077
STEP  R 000106
NEXT  R 000116
MORE  R 000122
OVFLO R 000134
DONE  R 000137
DCOMP R 000143
INIT  R 000150
SHIFT R 000163
BINNR R 000201
BCDNR R 000203
SIGN  R 000205
RIN   R 000206
COUNT R 000207
TCOMP R 000210
ITABL R 000212
JTABL R 000213
M4    R 000214
ITA   R 000215
JTA   R 000216
TABLE R 000217
TABLF R 000227
BILIM R 000237
BCLIM R 000241
** NO ERRORS*
```

```
0001                    ASMB,T,L,B
0002  00000                   NAM BDECB,7
0003*
0004                          ENT @DBIN,@BDEC
0005*
0006* BDECB IS TO BE USED AS A SUBROUTINE. BDECB CONTAINS
0007* TWO CONVERSION ROUTINES.  THE FIRST, @DBIN, CONVERTS
0008* A DBL PRECISION BCD NUMBER LOCATED IN THE A AND B
0009* REGISTERS TO A DBL PRECISION BINARY NUMBER LOCATED
0010* IN A AND B REGISTERS UPON EXIT FROM @DBIN.
0011*
0012* THE SECOND ROUTINE, @BDEC, PERFORMS THE INVERSE
0013* OPERATION, THAT OF CONVERTING A DOUBLE PRECISION
0014* BINARY NUMBER LOCATED IN THE A AND B REGISTERS TO A
0015* DBL PRECISION BCD NUMBER LOCATED IN THE A AND B
0016* REGISTERS UPON EXIT FROM @BDEC. BIT(15) CONTAINS THE
0017* SIGN OF BCD NUMBER. THE ABSOLUTE DECIMAL VALUE OF THE
0018* BINARY NUMBER MUST BE NO GREATED THAT 79,999,999 IN
0019* ORDER THAT THE BCD NUMBER FIT INTO 31 BITS. IF THE
0020* ABSOLUTE VALUE OF THE BINARY NUMBER IS LARGER THAN
0021* THE ABOVE LIMIT VALUE, THE LIMIT VALUE IS RETURNED
0022* IN THE A AND B REGISTERS AS THE BCD RESULT.
0023*
0024* THE A REGISTER CONTAINS THE LEAST SIGNIFICANT BITS
0025* OF THE DBL PRECISION NUMBERS MENTIONED ABOVE.
0026*
0027*
0028  00000 000000  @DBIN NOP             ENTER @DBIN WITH BCD NR IN A AND
0029  00001 072203R       STA BCDNR       B REGS. BIT(15) CONTAINS SIGN.
0030  00002 076204R       STB BCDNR+1     STORE BCD NR.
0031  00003 016150R       JSB INIT        INITIALIZE DIGIT COUNTER, SIGN
0032  00004 072201R       STA BINNR       FLAG, TABLE ADDRESSES AND
0033  00005 072202R       STA BINNR+1     STORAGE FOR BIN NR.
0034  00006 006020        SSB             EXAMINE SIGN OF BCD NR.
0035  00007 036205R       ISZ SIGN        IF NEG, SET SIGN=1. ELSE SIGN=0.
0036  00010 005665        ELB,CLE,ERB     CLEAR SIGN BIT, B(15) OF BCD NR.
0037  00011 076204R       STB BCDNR+1     STORE BCD NR WITH CLEARED SIGN.
0038  00012 016163R CONV1 JSB SHIFT       ROTATE BCD NR 4 BITS LEFT.
0039  00013 012230R       AND TABLF+1     EXAMINE 4 RIGHTMOST BITS; LOOK
0040  00014 002003        SZA,RSS         AT BCD DIGIT. IF DIGIT IS ZERO,
0041  00015 026032R       JMP NEXT1       BYPASS FOLLOWING MULTIPLICATION.
0042  00016 003004        CMA,INA         SET MULTIPLICATION COUNT TO COMP
0043  00017 072206R       STA RIN         OF CURRENT BCD DIGIT.
0044  00020 062201R       LDA BINNR       LOAD CURRENT VALUE OF BINARY NR.
0045  00021 066202R       LDB BINNR+1
0046  00022 142212R       ADA ITABL,I     ADD CURRENT TABLE VALUE, 1E+N,
0047  00023 002140        SEZ,CLE         WHERE N=7,6,...,1,0.
0048  00024 006004        INB             ADDITION DONE NR OF TIMES EQUAL
0049  00025 146213R       ADB JTABL,I     TO CURRENT VALUE OF BCD DIGIT.
0050  00026 036206R       ISZ RIN         WHEN COUNT IS ZERO, ADDITION
0051  00027 026022R       JMP *-5         OF CONTRIBUTION FROM CURRENT BCD
0052  00030 072201R       STA BINNR       DIGIT TO BIN NR IS COMPLETE.
0053  00031 076202R       STB BINNR+1     STORE NEW BIN NR.
0054  00032 036207R NEXT1 ISZ COUNT       INCREMENT BCD DIGIT COUNT. IF
0055  00033 026035R       JMP MORE1       COUNT<0 MORE DIGITS REMAIN.
0056  00034 026040R       JMP DONE1       IF COUNT=0, CONVERSION IS DONE,
```

```
0057  00035 036212R MORE1 ISZ ITABL     INCREMENT TABLE ADDRESSES.
0058  00036 036213R       ISZ JTABL
0059  00037 026012R       JMP CONV1     GO GET NEXT BCD DIGIT.
0060  00040 062201R DONE1 LDA BINNR     WHEN CONVERSION IS COMPLETE,
0061  00041 066202R       LDB BINNR+1   LOAD A AND B REGS WITH COMPUTED
0062  00042 000066       CLE,ELA       BIN NR.
0063  00043 042205R       ADA SIGN
0064  00044 001500       ERA           LOAD SIGN INTO E REGISTER.
0065  00045 002141       SEZ,CLE,RSS   IF SIGN OF BCD NR WAS POSITIVE,
0066  00046 026050R       JMP EXIT1     THEN EXIT @DBIN
0067  00047 016143R       JSB DCOMP     IF SIGN WAS NEGATIVE, COMPLEMENT
0068  00050 126000R EXIT1 JMP @DBIN,I   BIN NR, THEN EXIT @DBIN.
0069*
0070*
0071*
0072  00051 000000  @BDEC NOP           ENTER @BDEC WITH BINARY NR IN
0073  00052 072201R       STA BINNR     A AND B REGISTERS.
0074  00053 076202R       STB BINNR+1   STORE BIN NR.
0075  00054 016150R       JSB INIT      INITIALIZE DIGIT COUNTER, SIGN
0076  00055 072203R       STA BCDNR     FLAG, TABLE ADDRESSES AND
0077  00056 072204R       STA BCDNR+1   STORAGE FOR BCD NR.
0078  00057 006021       SSB,RSS       EXAMINE SIGN OF BINARY NR.
0079  00060 026067R       JMP SIZE      IF POS, GO CHECK SIZE OF BIN NR.
0080  00061 036205R       ISZ SIGN      IF NEG, SET SIGN=1, AND COMP BIN
0081  00062 062201R       LDA BINNR     NR. CONVERSION OF NEG BIN NR
0082  00063 066202R       LDB BINNR+1   PROCEEDS ON ABS VALUE OF BIN NR.
0083  00064 016143R       JSB DCOMP     SIGN IS ADDED TO BCD NR AS FINAL
0084  00065 072201R       STA BINNR     STEP. STORE COMPLEMENT OF NEG
0085  00066 076202R       STB BINNR+1   BIN NR.
0086  00067 062237R SIZE  LDA BILIM     LOAD COMPLEMENT OF LARGET ST
0087  00070 066240R       LDB BILIM+1   PERMISSIBLE BIN NR.
0088  00071 042201R       ADA BINNR     ADD ABSOLUTE BINARY NR TO BE
0089  00072 002140       SEZ,CLE       CONVERTED.
0090  00073 006004       INB
0091  00074 046202R       ADB BINNR+1
0092  00075 006121       CLE,SSB,RSS   COMPARE SIZES. IF BIN NR TOO
0093  00076 026134R       JMP OVFLO     LARGE, SKIP CONVERSION.
0094  00077 162212R CONV  LDA ITABL,I   LOAD AND COMPLEMENT THE CURRENT
0095  00100 166213R       LDB JTABL,I   TABLE VALUE, 1E+N, WHERE
0096  00101 016143R       JSB DCOMP     N=7,6,....1,0.
0097  00102 072210R       STA TCOMP     STORE THIS COMPLEMENT.
0098  00103 076211R       STB TCOMP+1
0099  00104 062201R       LDA BINNR     LOAD BINARY NR TO BEGIN
0100  00105 066202R       LDB BINNR+1   CONVERSION TO BCD NR.
0101  00106 042210R STEP  ADA TCOMP     SUBTRACT CURRENT TABLE VALUE
0102  00107 002140       SEZ,CLE       FROM CURRENT VALUE OF BIN NR.
0103  00110 006004       INB           IF SUBTRACTION YIELDS A POSITIVE
0104  00111 046211R       ADB TCOMP+1   REMAINDER, CURRENT BCD DIGIT IS
0105  00112 006120       CLE,SSB       INCREMENTED AND PROCESS REPEATS.
0106  00113 026116R       JMP NEXT      WHEN REMAINDER TURNS NEGATIVE,
0107  00114 036203R       ISZ BCDNR     COMPUTATION OF CURRENT BCD DIGIT
0108  00115 026106R       JMP STEP      IS COMPLETE.
0109  00116 036207R NEXT  ISZ COUNT     DIGIT COUNT INCREMENTED. IF
0110  00117 026122R       JMP MORE      COUNT<0, MORE DIGITS REMAIN.
0111  00120 062203R       LDA BCDNR     IF COUNT=0, CONVERSION IS DONE
0112  00121 026137R       JMP DONE      AND LEAST HALF OF BCD NR LOADED.
```

```
0113  00122 142212R MORE   ADA ITABL,I   PREPARE FOR COMPUTATION OF NEXT
0114  00123 002140         SEZ,CLE       BCD DIGIT BY ADDING BACK LAST
0115  00124 006004         INB           TABLE VALUE SUBTRACTED. THIS
0116  00125 146213R        ADB JTABL,I   YIELDS CORRECT BINARY REMAINDER
0117  00126 072201R        STA BINNR     WHICH IS THEN STORED.
0118  00127 076202R        STB BINNR+1
0119  00130 036212R        ISZ ITABL     INCREMENT TABLE ADDRESSES.
0120  00131 036213R        ISZ JTABL     BCD NR SHIFTED 4 BITS LEFT.
0121  00132 016163R        JSB SHIFT     4 RIGHT BTS TO ZERO. INITIALIZES
0122  00133 026077R        JMP CONV      NEXT BCD DIGIT. GO BACK.
0123  00134 062241R OVFLO  LDA BCLIM     IF BIN NR TOO LARGE, LIMIT VALUE
0124  00135 066242R        LDB BCLIM+1   IN BCD FORM IS LOADED IN A AND B
0125  00136 076204R        STB BCDNR+1   REGS. STORE MOST SIGNIF HALF.
0126  00137 066205R DONE   LDB SIGN      IF CONVERSION IS COMPLETE, SIGN
0127  00140 005300         RBR           OF BCD NR PLACED IN B(15) AND
0128  00141 046204R        ADB BCDNR+1   BCD NR IS PLACED IN A AND B
0129  00142 126051R        JMP @BDEC,I   REGS. EXIT @BDEC.
0130*
0131*
0132  00143 000000  DCOMP  NOP           DCOMP COMPUTES DBL PREC COMP OF
0133  00144 007000         CMB           A NR FOUND IN A AND B REGS.
0134  00145 003007         CMA,INA,SZA,RSS  WITH LEAST SIGNIF BITS IN
0135  00146 006004         INB           THE A REGISTER.
0136  00147 126143R        JMP DCOMP,I   EXIT DCOMP.
0137*
0138  00150 000000  INIT   NOP           INITIALIZATION SUBROUTINE.
0139  00151 062214R        LDA M4
0140  00152 001000         ALS           SET BCD DIGIT COUNT TO -8.
0141  00153 072207R        STA COUNT
0142  00154 062215R        LDA ITA       INITIALIZE TABLE ADDRESSES SO
0143  00155 072212R        STA ITABL     THAT FIRST VALUE (1E+7) WILL BE
0144  00156 062216R        LDA JTA       INITIALLY CALLED.
0145  00157 072213R        STA JTABL
0146  00160 002500         CLA,CLE       A AND E REGISTERS ARE CLEARED.
0147  00161 072205R        STA SIGN      SIGN FLAG IS CLEARED.
0148  00162 126150R        JMP INIT,I    EXIT INIT.
0149*
0150*
0151  00163 000000  SHIFT  NOP           ENTER SHIFT, A SUBROUTINE THAT
0152  00164 062214R        LDA M4        PERFORMS A DBL PREC ROTATION OF
0153  00165 072206R        STA RIN       CURRENT BCD NR LEFT 4 BITS.
0154  00166 062203R        LDA BCDNR     SHIFT COUNT, RIN, SET TO -4
0155  00167 066204R        LDB BCDNR+1
0156  00170 000066         CLE,ELA       BCD NR LOADED AND ROTATED LEFT
0157  00171 005600         ELB           ONE BIT AT A TIME.
0158  00172 002140         SEZ,CLE
0159  00173 002004         INA
0160  00174 036206R        ISZ RIN       WHEN COUNT BECOMES ZERO.
0161  00175 026170R        JMP *-5       ROTATION IS COMPLETE.
0162  00176 072203R        STA BCDNR     STORE SHIFTED BCD NR.
0163  00177 076204R        STB BCDNR+1
0164  00200 126163R        JMP SHIFT,I   EXIT SHIFT
0165*
0166*STORAGE AND CONSTANT ALLOCATION
0167*
0168*
```

```
0169  00201 000000  BINNR BSS 2          STORAGE FOR BINARY NR
0170  00203 000000  BCDNR BSS 2                  BCD NR
0171  00205 000000  SIGN  BSS 1                  SIGN FLAG
0172  00206 000000  RIN   BSS 1          SHIFT AND MULTIPLICATION COUNT
0173  00207 000000  COUNT BSS 1                  BCD DIGIT COUNT
0174  00210 000000  TCOMP BSS 2          COMP OF CURRENT TABLE VALUE
0175  00212 000000  ITABL BSS 1              CURRENT TABLE ADDRESSES
0176  00213 000000  JTABL BSS 1
0177  00214 177774  M4    DEC -4         SETS SHIFT AND DIGIT COUNTERS.
0178  00215 000217R ITA   DEF TABLE      USED TO INITIALIZE TABLE
0179  00216 000227R JTA   DEF TABLF      ADDRESSES.
0180  00217 113200  TABLE OCT 113200,41100     TABLE CONTAINS THE LEAST
      00220 041100
0181  00221 103240        OCT 103240,23420  SIGNIF BITS OF THE 8 DECIMAL
      00222 023420
0182  00223 001750        OCT 1750,144      NRS 1E+N,WHERE N=7,6,...,1,0.
      00224 000144
0183  00225 000012        OCT 12,1
      00226 000001
0184  00227 000230  TABLF OCT 230,17     TABLE CONTAINS THE MOST SIGNIF
      00230 000017
0185  00231 000001        OCT 1,0        BITS OF THE 8 DECIMAL NRS 1E+N,
      00232 000000
0186  00233 000000        OCT 0,0        WHERE N=7,6,...,1,0. 17 IS ALSO
      00234 000000
0187  00235 000000        OCT 0,0        USED AS A MASK IN @DBIN.
      00236 000000
0188  00237 046000  BILIM OCT 46000      -8E+7, THE LARGEST BIN NR THAT
0189  00240 175473        OCT 175473     CAN PROPERLY BE CONVERTED.
0190  00241 114631  BCLIM OCT 114631     79,999,999 IN BCD FORM. LOADED
0191  00242 074631        OCT 74631      WHEN BIN NR TOO LARGE.
0192*
0193                      END
** NO ERRORS*
```

APPENDIX C.--ASSEMBLER LISTING OF DVR-55, THE DOS-M DRIVER FOR MCA FUNCTION CONTROL

```
                    ASMB,B,T,L

0001
I.55    R 000000
C.55    R 000073
FCSET   R 000030
MSTOP   R 000033
I06     R 000040
FRSET   R 000043
JEXIT   R 000054
KEXIT   R 000057
FWSET   R 000066
IEXIT   R 000071
I05     R 000101
CXT1    R 000111
OUTP1   R 000117
I12     R 000130
I14     R 000131
I15     R 000144
I16     R 000155
SETIO   R 000157
STPCK   R 000201
OTMCA   R 000211
I01     R 000213
I02     R 000214
I04     R 000215
LIA     R 000217
.100    R 000220
.1100   R 000221
.1000   R 000222
.3000   R 000223
.4000   R 000224
P1      R 000225
P2      R 000226
CHKPT   R 000227
FCNWD   R 000230
TCNWD   R 000231
TEMP1   R 000232
RDWRT   R 000233
I03     R 000234
IO        000000
A         000000
B         000001
.1        000054
.2        000055
.3        000056
.7        000062
EQT4      000206
EQT9      000213
EQT10     000214
EQT11     000215
EQT12     000216
EQT13     000217
EQT14     000220
**   NO ERRORS*
```

```
0001                ASMB,B,T,L
0003  00000             NAM DVR55,0
0004                    ENT I.55,C.55
0005*
0006*    ************************************************************
0007*    *      TWIN CITIES METALLURGY RESEARCH CENTER              *
0008*    *                BUREAU OF MINES                           *
0009*    *           U.S. DEPT. OF THE INTERIOR                     *
0010*    *                                                          *
0011*    *  PROGRAM NAME - DVR55                                    *
0012*    *  DESCRIPTION  - DOS-M DRIVER FOR 5402B MCA SYSTEM        *
0013*    *                 USE WITH MCA LIBRARY (.MCA)              *
0014*    *  AUTHOR       - FRANKLIN B.W. WOODBURY (612-725-4645)     *
0015*    *                                                          *
0016*    *  DEVELOPED AS PART OF THE AEC CALIFORNIUM-252 MARKET     *
0017*    *  EVALUATION PROGRAM, UNDER INTERAGENCY AGREEMENT NO.     *
0018*    *  AT(38-1)-747                                            *
0019*    ************************************************************
0020*
0021*
0022*      **********  INITIATION SECTION  **********
0023*
0024  00000 000000  I.55  NOP
0025  00001 016157R       JSB SETIO      CONFIGURE I/O INSTRUCTION
0026  00002 060056        LDA .3         SET UP $EX18 RETURN CODE FOR
0027*                                         DEVICE NOT READY
0028  00003 164206        LDB EQT4,I     GET MCA STATUS WORD
0029  00004 006020        SSB            SKIP NEXT IF BIT 15=0
0030  00005 016201R       JSB STPCK      UNIT IS BUSY GO TO STOP CHECK
0031*
0032*  SETUP EQT TABLE VALUES
0033*
0034  00006 164214        LDB EQT10,I    GET PARAMETER OR BUFFER ADDRESS
0035  00007 174216        STB EQT12,I    STORE
0036  00010 164215        LDB EQT11,I    GET BUFFER LENGTH
0037  00011 006020        SSB            NEGATIVE?
0038  00012 026014R       JMP *+2            NO
0039  00013 007004        CMB,INB        MAKE NEGATIVE
0040  00014 006003        SZB,RSS        CHECK FOR ZERO LENGTH
0041  00015 007400        CCB            MAKE B REG NEGATIVE ONE
0042  00016 174217        STB EQT13,I    STORE
0043*
0044*    DETERMINE TYPE OF REQUEST
0045*
0046  00017 110213        AND EQT9,I     CHECK REQUEST CODE
0047  00020 050056        CPA .3          IS IT A CONTROL REQUEST?
0048  00021 026030R       JMP FCSET          YES, GO TO CONTROL SET
0049  00022 050055        CPA .2              NO, IS IT A WRITE REQUEST?
0050  00023 026066R       JMP FWSET              YES, GO TO WRITE SET
0051  00024 050054        CPA .1                 NO, IS IT A READ REQUEST?
0052  00025 026043R       JMP FRSET       YES, GO TO READ SET
0053  00026 060055        LDA .2         NO, ILLEGAL REQUEST
0054  00027 126000R       JMP I.55,I     EXIT DRIVER
0055*
```

```
0057*   SET CONTROL FUNCTION
0058*
0059   00030 000000  FCSET NOP
0060   00031 164216        LDB EQT12,I   GET PARAMETER
0061   00032 076231R       STB TCNWD     STORE PARAMETER IN THE
0062*                                         TEMPORARY CONTROL WORD
0063   00033 000000  MSTOP NOP
0064   00034 062231R       LDA TCNWD     LOAD PARAMETER
0065   00035 003000        CMA           CORRECT LOGICAL SENSE
0066   00036 072230R       STA FCNWD     STORE IN FUNCTION CONTROL WORD
0067   00037 016211R       JSB OTMCA      OUTPUT FUNCTION CONTROL WORD
0068*                                         TO MCA
0069   00040 106700  I06   CLC IO        CLEAR CONTROL BIT
0070*
0071   00041 062235R       LDA =B4       SET IMMEDIATE COMPLETION CODE
0072   00042 126000R       JMP I.55,I                          EXIT DRIVER
0073*
0074*   SET CONTROLS FOR A READ FROM MCA, AND READ
0075*
0076   00043 062225R FRSET LDA P1        ADJUST RETURN FROM
0077   00044 072073R       STA C.55      COMPLETION SECTION TO "JEXIT"
0078   00045 164215        LDB EQT11,I   CHECK FOR ONE WORD READ
0079   00046 054054        CPB .1           IF ONE WORD
0080   00047 026057R       JMP KEXIT     GO TO BIT15 CHECK
0081   00050 062233R       LDA RDWRT     LOAD RDWRT CONTROL WORD
0082   00051 003000        CMA           CORRECT LOGICAL SENSE
0083   00052 072230R       STA FCNWD     STORE IN FUNCTION CONTROL WORD
0084   00053 016211R       JSB OTMCA      OUTPUT FUNCTION CONTROL WORD
0085*                                         TO MCA
0086   00054 002400  JEXIT CLA            A=0, SUCCESSFUL INITIATION CODE
0087   00055 072232R       STA TEMP1     INITIALIZE CHARACTER COUNTER
0088   00056 126000R       JMP I.55,I    RETURN TO IOC
0089*
0090*    CHECK IN-OPERATION LIGHT
0091*
0092   00057 062236R KEXIT LDA =B100000  ROUTINE TO CHECK BIT15
0093   00060 003000        CMA                OPERATIONAL LIGHT
0094   00061 072230R       STA FCNWD           ON OR OFF
0095   00062 016211R       JSB OTMCA     OUTPUT FUNCTION WORD
0096   00063 002400        CLA           A=0, SUCCESSFUL INITIATION
0097   00064 072232R       STA TEMP1     INITIALIZE CHARACTER COUNTER
0098   00065 126000R       JMP I.55,I    ---- RETURN TO IOC ----
0099*
0100*
0101*
0102*   SET CONTROLS FOR A WRITE TO MCA, AND WRITE
0103*
0104   00066 062226R FWSET LDA P2        ADJUST RETURN FROM
0105   00067 072073R       STA C.55      COMPLETION SECTION TO "IEXIT"
0106   00070 026117R       JMP OUTP1     GO TO COMPLETION SECTION
0107   00071 002400  IEXIT CLA           A=0, SUCCESSFUL INITIATION
0108   00072 126000R       JMP I.55,I    ---- RETURN TO IOC ----
```

```
0110*     ************  COMPLETION SECTION ************
0111*
0112*
0113  00073 000000  C.55  NOP
0114  00074 016157R       JSB SETIO      CONFIGURE I/O INSTRUCTIONS
0115*
0116*
0117  00075 164213        LDB EQT9,I     GET REQUEST CODE
0118  00076 006011        SLB,RSS        READ REQUEST?
0119  00077 026117R       JMP OUTP1          NO, GO TO WRITE SECTION
0120  00100 036232R       ISZ TEMP1          YES, PROCESS IT
0121*
0122*   ***  READ SECTION  ***
0123*
0124  00101 102500  I05   LIA IO           READ WORD FROM MCA
0125  00102 003000        CMA              CORRECT LOGICAL SENSE
0126  00103 164216        LDB EQT12,I      GET BUFFER ADDRESS
0127  00104 134216        ISZ EQT12,I            INCREMENT BUFFER
0128  00105 170001        STA B,I          STORE WORD IN BUFFER
0129  00106 134217        ISZ EQT13,I      REDUCE BUFFER LENGTH BY ONE
0130  00107 026111R       JMP CXT1         CONTINUE
0131  00110 026144R       JMP I15            EXIT, READ IS COMPLETED
0132*
0133*  CONTINUATION EXIT
0134*
0135  00111 062233R CXT1  LDA RDWRT        LOAD RDWRT CONTROL WORD
0136  00112 003000        CMA              CORRECT LOGICAL SENSE
0137  00113 072230R       STA FCNWD          STORE IN FUNCTION CONTROL WORD
0138  00114 016211R       JSB OTMCA        OUTPUT FCNWD TO MCA
0139  00115 036073R       ISZ C.55         CONTINUE
0140  00116 126073R       JMP C.55,I       COMPLETED-EXIT
0141*
0142*   ***   WRITE SECTION   ***
0143  00117 002400  OUTP1 CLA              IF BUFFER LENGTH = ZERO
0144  00120 150217        CPA EQT13,I            GO TO
0145  00121 026144R       JMP I15                  COMPLETION EXIT
0146  00122 164216        LDB EQT12,I      GET CURRENT BUFFER ADDRESS
0147  00123 134216        ISZ EQT12,I      INCREMENT ADDRESS
0148  00124 160001        LDA B,I          GET WORD
0149  00125 134217        ISZ EQT13,I      INCREMENT WORD COUNT
0150  00126 000000        NOP
0151  00127 003000        CMA              CORRECT LOGICAL SENSE
0152  00130 102600  I12   OTA IO           OUTPUT WORD TO INTERFACE
0153  00131 103700  I14   STC IO,C         TURN ON MCA
0154  00132 000000        NOP
0155  00133 000000        NOP              DELAY TO
0156  00134 000000        NOP                 ALLOW MCA TO RESPOND
0157  00135 000000        NOP
0158  00136 000000        NOP
0159  00137 000000        NOP
0160  00140 000000        NOP
0161  00141 000000        NOP
0162  00142 036073R       ISZ C.55         ADJUST RETURN TO P+2
0163  00143 126073R       JMP C.55,I       ---- RETURN TO CIC ----
```

```
0165*
0166*     STATUS AND COMPLETION EXIT
0167*
0168*
0169*
0170  00144 102500  I15   LIA IO          GET STATUS WORD FROM MCA
0171  00145 012237R       AND =B377       STRIP OFF HIGH ORDER BITS
0172  00146 070001        STA B           AND SAVE IN B
0173  00147 160206        LDA EQT4,I      REMOVE PREVIOUS
0174  00150 012240R       AND =B177400
0175  00151 030001        IOR B           SET IN NEW
0176  00152 170206        STA EQT4,I      STATUS BITS
0177  00153 002400        CLA             SET NORMAL RETURN
0178  00154 066232R       LDB TEMP1          SET(B) = TRANSMISSION LOG
0179  00155 106700  I16   CLC IO
0180  00156 126073R       JMP C.55,I      EXIT FOR COMPLETION
0181*
0182* SUBROUTINE TO CONFIGURE I/O
0183*
0184  00157 000000  SETIO NOP
0185  00160 032217R       IOR LIA
0186  00161 072101R       STA I05          <LIA>
0187  00162 072144R       STA I15
0188*
0189  00163 042220R       ADA .100
0190  00164 072214R       STA I02          <OTA>
0191  00165 072130R       STA I12
0192*
0193  00166 042220R       ADA .100
0194  00167 072234R       STA I03         <STC>
0195*
0196  00170 042222R       ADA .1000
0197  00171 072215R       STA I04          <STC,C>
0198  00172 072131R       STA I14
0199*
0200  00173 042223R       ADA .3000
0201  00174 072040R       STA I06             <CLC>
0202  00175 072155R       STA I16
0203*
0204  00176 042222R       ADA .1000
0205  00177 072213R       STA I01          <CLC,C>
0206*
0207  00200 126157R       JMP SETIO,I
0208*
```

```
0210*
0211*SUBROUTINE STOP CHECK
0212*
0213  00201 000000  STPCK NOP
0214  00202 164214        LDB EQT10,I   GET PARAMETER
0215  00203 174216        STB EQT12,I     STORE PARAMETER IN EQT 12
0216  00204 076231R       STB TCNWD       STORE PARA. IN TEMP. CONTROL
0217  00205 056227R       CPB CHKPT     IS PARAMETER A STOP
0218  00206 026033R       JMP MSTOP       YES, GO TO STOP ROUTINE
0219  00207 060056        LDA .3           NO,  EQUIPMENT IS NOT READY
0220  00210 126000R       JMP I.55,I        EXIT DRIVER
0221*
0222*
0223*
0224*   SUBROUTINE OUTPUT TO MCA
0225*
0226*
0227  00211 000000  OTMCA NOP
0228  00212 062230R       LDA FCNWD     LOAD FUNCTION CONTROL WORD
0229  00213 107700  I01   CLC IO,C      CLEAR CONTROL BIT, CLEAR FLAG
0230  00214 102600  I02   OTA IO        OUTPUT A INTO I/O CARD
0231  00215 103700  I04   STC IO,C      SET CONTROL BIT, CLEAR
0232  00216 126211R       JMP OTMCA,I   RETURN
0233*
0234*
0235*
0236*
0237  00217 102500  LIA   LIA 0
0238  00220 000100  .100  OCT 100
0239  00221 001100  .1100 OCT 1100
0240  00222 001000  .1000 OCT 1000
0241  00223 003000  .3000 OCT 3000
0242  00224 004000  .4000 OCT 4000
0243  00225 000053R P1    DEF JEXIT-1
0244  00226 000070R P2    DEF IEXIT-1
0245  00227 000001  CHKPT OCT 1
0246  00230 000000  FCNWD BSS 1
0247  00231 000000  TCNWD BSS 1
0248  00232 000000  TEMP1 BSS 1
0249  00233 060000  RDWRT OCT 60000
0250  00234 000000  I03   BSS 1
0251*
0252*
```

```
0254*
0255*
0256*  BASE PASE COMMUNICATION AREA
0257  00000          IO     EQU 0
0258  00000          A      EQU 0
0259  00001          B      EQU 1
0260  00054          .1     EQU 54B
0261  00055          .2     EQU 55B
0262  00056          .3     EQU 56B
0263  00062          .7     EQU 62B
0264*
0265*
0266*
0267*
0268*
0269*EQUIPMENT TABLE COMMUNICATION AREA
0270  00206          EQT4   EQU 206B
0271  00213          EQT9   EQU 213B
0272  00214          EQT10  EQU 214B
0273  00215          EQT11  EQU 215B
0274  00216          EQT12  EQU 216B
0275  00217          EQT13  EQU 217B
0276  00220          EQT14  EQU 220B
0277*
0278*
0279*
      00235 000004
      00236 100000
      00237 000377
      00240 177400
0280                        END
**  NO ERRORS*
```

APPENDIX D.--FORTRAN LISTINGS OF MCA-DISC UTILITY PACKAGE

MCA-DISC Utility Package

The programs and subroutines in the MCA-DISC utility package make use of .MCA, the DOS-M/MCA/FORTRAN library, to operate the MCA control functions and to allow data transfer between the MCA, the computer, and the disc storage device. These programs are

DTMCA - Data Transfer from MCA is a program that allows the operator to transfer spectrum data from the MCA unit to the disc storage device. In addition, this program also creates the disc file in which the data is to be stored and gives a name to that file.[1]

DSTOR - Data STORe is a subroutine that is used within another program to perform the same functions as the program DTMCA. The calling parameter LU determines the input logical unit number of the device from which the subroutine will obtain the name of the file to be created while the parameter V is the name of the data array containing the spectrum data.

DINT8 - Data INTo 8 is a program that retrieves spectrum data stored in a particular disc file and places this data in the MCA. The spectrum data is displayed on the MCA scope and program halts until the operator proceeds to next operation.

DTRET - DaTa RETrieve is a subroutine that is used within another program to perform the same functions as the program DINT8. The calling parameters LU and V are used the same as in DSTOR.

DOUT1 - Data OUt To 1 is a program that retrieves spectrum data from a disc file and lists the data values on the list device.

DOUTC - Data OUt To Computer is a subroutine to retrieve spectrum data from a disc file and places it in the common data area for use by the calling program.

---

[1]Proper use of DSTOR and DTMCA requires that a subroutine DIREN be part of the computer library. This subroutine is available from HP contributed library, 22416A. The subroutine provides a method of establishing directory entries for discs filed under program control. Files are established by calling the appropriate entry point of DIREN, in this case the entry point is STBNM, which indicates that the new file is to be a binary file for numerical data. The calling parameters define the name of the new file and its length in sectors.

```
Call STBNM (INAME, 16),
Dimension INAME (3),
          INAME (1) = 2HXX,
          INAME (2) = 2HXX,
          INAME (3) = 2HX,
```

where XXXXX is a 5-character file name.
A spectrum requires 16 sectors to store 1,024-floating point data words.

CALIB - CALIBrate is a program used to determine the energy calibration of a particular spectrum. This program requires the operator to input the starting and ending channels for both a low- and a high-energy peak and the respective energy values. The program then calculates the zero offset and the gain of the spectrum. The program has an optional loop to repeat with new set of peaks or to terminate.

CENTD - CENTroiD is a subroutine to calculate the centroid of a selected spectrum peak. The subroutine parameters are

L = lower boundary channel of peak edge,

U = upper boundary channel of peak edge,

C = the centroid value returned to the calling program,

F = the partial 1st moment of the peak,

E = the partial 2nd moment of the peak,

and A = the peak area returned to the calling program.

NORML - NORMaL is a program that does a log normalization of the spectrum data.

PSMTH - Peak SMooTH is a program that smooths the spectrum data by averaging adjacent channels. The program has optional loop that allows repetition of the smoothing operation.

MRAMP - MCA RAMP is a program used to test the single channel read-write functions of the multichannel analyzer. It creates a display on the MCA scope where the data value in a particular channel equals that channel.

```
0023          PROGRAM DTMCA
0024          DIMENSION INAME(3),V(1024)
0025          WRITE(1,4000)
0026          READ(1,3000)INAME
0027          CALL STOPM
0028          CALL MCASO
0029          DO 10 J=1,1011,10
0030          READ(8,1000) M,(V(K),K=J,J+9)
0031       10 CONTINUE
0032          READ(8,1024)M,(V(K),K=1021,1024)
0033          CALL STBNM(INAME,16)
0034          CALL EXEC(15,103B,V,2048,INAME,0)
0035          WRITE(1,2500) INAME
0036          CALL STOPM
0037     2500 FORMAT(1H ,"SPECTRUM STORED ON DISC IN FILE -   ",2A2,A1)
0038     1000 FORMAT(I4,10F7.0)
0039     1024 FORMAT(I4,4F7.0)
0040     3000 FORMAT(2A2,A1)
0041     4000 FORMAT(1H ,"GIVE NAME FOR FILE")
0042          END

**  NO ERRORS**     PROGRAM = 02239       COMMON = 00000
```

```
0001  FTN4,L,B
0002        SUBROUTINE DSTOR(LU,V)
0003        DIMENSION INAME(3),V(1024)
0004        WRITE(1,4000)
0005        READ(LU,3000)INAME
0006        CALL STOPM
0007        CALL MCASO
0008        DO 10 J=1,1011,10
0009        READ(8,1000) M,(V(K),K=J,J+9)
0010     10 CONTINUE
0011        READ(8,1024)M,(V(K),K=1021,1024)
0012        CALL STBNM(INAME,16)
0013        CALL EXEC(15,103B,V,2048,INAME,0)
0014        WRITE(1,2500) INAME
0015        CALL STOPM
0016   2500 FORMAT(1H ,"SPECTRUM STORED ON DISC IN FILE -   ",2A2,A1)
0017   1000 FORMAT(I4,10F7.0)
0018   1024 FORMAT(I4,4F7.0)
0019   3000 FORMAT(2A2,A1)
0020   4000 FORMAT(1H ,"GIVE NAME FOR FILE")
0021        RETURN
0022        END

**  NO ERRORS**     PROGRAM = 00192       COMMON = 00000
```

```
0043          PROGRAM DINT8
0044          DIMENSION INAME(3),V(1024)
0045          CALL STOPM
0046          CALL ERASE
0047          WRITE(1,3100)
0048          READ(1,3000) INAME
0049          CALL EXEC (14,103B,V,2048,INAME,0)
0050          CONTINUE
0051          CALL MCASI
0052          DO 10 K=1,1011,10
0053          WRITE(8,1000)(V(J),J=K,K+9)
0054       10 CONTINUE
0055          WRITE(8,1024)(V(J),J=1021,1024)
0056          CONTINUE
0057          CALL STOPM
0058          CONTINUE
0059          IV=1024
0060          D=V(IV)
0061          IA=IV-1
0062          CALL PUTDV(IA,D)
0063          WRITE(1,3200)
0064     1000 FORMAT("9999",10F8.0)
0065     1024 FORMAT("9999",4F8.0)
0066     3000 FORMAT(2A2,A1)
0067     3100 FORMAT(1H ,"INPUT FILE NAME")
0068     3200 FORMAT(1H ,"DATA FILE IS NOW IN MCA")
0069          CALL DISPF
0070          PAUSE
0071          CALL STOPM
0072          END

**  NO ERRORS**     PROGRAM = 02251       COMMON = 00000
```

```
0093          SUBROUTINE DTRET(LU,V)
0094          DIMENSION INAME(3),V(1024)
0095          CALL STOPM
0096          CALL ERASE
0097          WRITE(1,3100)
0098          READ(LU,3000)INAME
0099          CALL EXEC (14,103B,V,2048,INAME,0)
0100          CONTINUE
0101          CALL MCASI
0102          DO 10 K=1,1011,10
0103          WRITE(8,1000)(V(J),J=K,K+9)
0104       10 CONTINUE
0105          WRITE(8,1024)(V(J),J=1021,1024)
0106          CONTINUE
0107          CALL STOPM
0108          CONTINUE
0109          IV=1024
0110          D=V(IV)
0111          IA=IV-1
0112          CALL PUTDV(IA,D)
0113          WRITE(1,3200)
0114     1000 FORMAT("9999",10F8.0)
0115     1024 FORMAT("9999",4F8.0)
0116     3000 FORMAT(2A2,A1)
0117     3100 FORMAT(1H,"INPUT FILE NAME")
0118     3200 FORMAT(1H ,"DATA FILE IS NOW IN MCA")
0119          CALL STOPM
0120          RETURN
0121          END

**  NO ERRORS**     PROGRAM = 00199       COMMON = 00000
```

```
0073          PROGRAM DOUT1
0074          DIMENSION INAME(3),V(1024)
0075          WRITE(1,3100)
0076          READ(1,3000) INAME
0077          CALL EXEC (14,1038,V,2048,INAME,0)
0078          DO 10 I=1,102
0079          J=(10*(I-1))+1
0080          M=J-1
0081          WRITE(6,1000) M
0082          WRITE(6,1010) (V(K),K=J,J+9)
0083       10 CONTINUE
0084          M=1020
0085          WRITE(6,1000) M
0086          WRITE(6,2010) (V(K),K=1021,1024)
0087     1000 FORMAT(I4)
0088     1010 FORMAT(10I7)
0089     2010 FORMAT(4I7)
0090     3000 FORMAT(2A2,A1)
0091     3100 FORMAT(1H ,"INPUT FILE NAME")
0092          END

** NO ERRORS**     PROGRAM = 02217       COMMON = 00000
```

```
0122          SUBROUTINE DOUTC
0123          COMMON V(1024)
0124          DIMENSION INAME(3)
0125          WRITE(1,3100)
0126          READ(1,3000) INAME
0127          CALL EXEC(14,103B,V,2048,INAME,0)
0128     3100 FORMAT(1H ,"INPUT FILE NAME")
0129     3000 FORMAT(2A2,A1)
0130           RETURN
0131           END

**  NO ERRORS**     PROGRAM = 00060       COMMON = 02048
```

```
0186          PROGRAM CALIB
0187          INTEGER U1,U2
0188          DIMENSION V(1024)
0189          LU=1
0190          CALL DTRET(LU,V)
0191       20 WRITE(6,2005)
0192          CALL DISPB
0193          READ(1,*)L1
0194          WRITE(6,2010)
0195          READ(1,*)U1
0196          CALL STOPM
0197          CALL CENTD(L1,U1,C1,X1,X2,X3)
0198          WRITE(6,2015)
0199          CALL DISPB
0200          READ(1,*)L2
0201          WRITE(6,2020)
0202          READ(1,*)U2
0203          CALL STOPM
0204          CALL CENTD(L2,U2,C2,X4,X5,X6)
0205          WRITE(6,2100) C1,C2
0206          WRITE(6,2200)
0207          READ(1,*)E1
0208          WRITE(6,2201)
0209          READ(1,*)E2
0210          G=(E2-E1)/(C2-C1)
0211          Z=E1-G*C1
0212          WRITE(6,2300) G
0213          WRITE(6,2310) Z
0214          WRITE(4,2320)G,Z
0215          WRITE(6,2400)
0216    2320  FORMAT(F10.6,F10.5)
0217          READ(1,*)ZZ
0218          IF (ZZ) 20,20,30
0219       30 CONTINUE
0220    2005  FORMAT(/,"INPUT LOWER BOUNDARY CHANNEL OF LOW-ENERGY PEAK")
0221    2010  FORMAT("INPUT UPPER BOUNDARY CHANNEL OF LOW-ENERGY PEAK")
0222    2015  FORMAT("INPUT LOWER BOUNDARY CHANNEL OF HIGH-ENERGY PEAK")
0223    2020  FORMAT("INPUT UPPER BOUNDARY CHANNEL OF HIGH-ENERGY PEAK")
0224    2100  FORMAT(/,2X,"THE PEAK CENTROIDS ARE",4X,F10.3,F10.3)
0225    2200  FORMAT(/,"INPUT ENERGY OF LOW ENERGY PEAK")
0226    2201  FORMAT("INPUT ENERGY OF HIGH ENERGY PEAK")
0227    2300  FORMAT(/,1X,"GAIN =",10X,F10.6,4X,"KEV/CHANNEL")
0228    2310  FORMAT(/,1X,"ZERO OFFSET =",2X,F10.6,5X,"KEV")
0229    2400  FORMAT(///,"TO STOP, TYPE'1'; TO REPEAT TYPE '0'")
0230          END

**  NO ERRORS**     PROGRAM = 02533       COMMON = 00000
```

```
0261          SUBROUTINE CENTD(L,U,C,F,E,A)
0262          REAL M, N
0263          INTEGER U
0264          S1=0.0
0265          S2=0.0
0266          A=0.0
0267          E=0.0
0268          F=0.0
0269          DO 100 I=L-2,L+2
0270          CALL GETDV(I,D1)
0271          S1=S1 +D1/5.0
0272      100 CONTINUE
0273          DO 110 J=U-2,U+2
0274          CALL GETDV(J,D2)
0275          S2=S2+D2/5.0
0276      110 CONTINUE
0277          M=(S2-S1)/(U-L)
0278          B=S1-M*L
0279          DO 120 K=L,U
0280          CALL GETDV(K,D3)
0281          N=D3-(M*K+B)
0282          A=A+N
0283          E=E+N*K
0284          F=F+(N*K*K)
0285      120 CONTINUE
0286          C=E/A
0287          RETURN
0288          END
```

** NO ERRORS** PROGRAM = 00209 COMMON = 00000

```
0155          PROGRAM NORML
0156          DIMENSION V1(1024)
0157          EQUIVALENCE (V1,V2)
0158          LU=1
0159          CALL DTRET(LU,V1)
0160          CALL DISPB
0161          PAUSE
0162          CALL STOPM
0163          IC=1
0164          CALL GETDV(IC,D)
0165      120 IC=IC+1
0166          CALL GETDV(IC,D1)
0167          IF (D.GT.D1)160,150
0168      150 D=D1
0169      160 IF(IC.EQ.1023)200,120
0170      200 D3=ALOG(D)
0171          RK=D/D3
0172          IC=1
0173      230 CALL GETDV(IC,D4)
0174          D5=RK*ALOG(D4+0.01)
0175          CALL PUTDV(IC,D5)
0176          IC=IC+1
0177          IF(IC.LT.1024)230,280
0178      280 CALL DISPB
0179          WRITE(1,2000)
0180          READ(1,*)XXX
0181          CALL STOPM
0182          IF (XXX)10,10,20
0183       10 CALL DSTOR(LU,V2)
0184     2000 FORMAT(/"TO STORE, TYPE'0';TO STOP, TYPE'1'")
0185       20 END

**  NO ERRORS**     PROGRAM = 02208       COMMON = 00000
```

```
0132          PROGRAM PSMTH
0133          DIMENSION V1(1024)
0134          EQUIVALENCE(V1,V2)
0135          LU=1
0136          CALL DTRET(LU,V1)
0137       10 IC1=2
0138          CALL GETDV(IC1-1,D1)
0139          CALL GETDV(IC1,D2)
0140      100 CALL GETDV(IC1+1,D3)
0141          S=(D1+2.0*D2+D3)/4.0
0142          CALL PUTDV(IC1,S)
0143          D1=D2
0144          D2=D3
0145          IC1=IC1+1
0146          IF(IC1.LT.1023)100,200
0147       20 CALL DSTOR(LU,V2)
0148      200 CALL DISPB
0149          WRITE(1,2000)
0150          READ(1,*)XXX
0151          CALL STOPM
0152          IF (XXX)10,20,30
0153     2000 FORMAT(/"ENTER: '-1' TO REPEAT,'0' TO STORE,'+1' TO STOP")
0154       30 END

** NO ERRORS**     PROGRAM = 02192       COMMON = 00000
```

```
0289          PROGRAM MRAMP
0290          A=0.
0291       10 DO 100 I=1,1024
0292          J=I-1
0293          CALL PUTDV(J,A)
0294          A=A+1.
0295      100 CONTINUE
0296          CALL DISPF
0297          PAUSE
0298       20 DO 200 K=1,1024
0299          L=K-1
0300          CALL GETDV(L,B)
0301          WRITE(1,1000)L,B
0302      200 CONTINUE
0303     1000 FORMAT (I4,F10.0)
0304          CALL ERASE
0305          GO TO 10
0306          END

** NO ERRORS**     PROGRAM = 00090        COMMON = 00000
```

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